GEOLOGY AND MINERALS OF MANITOBA

Geology and Minerals

OF

Manitoba

By

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A HANDBOOK

for

MINE PROSPECTING

in

MANITOBA

Geology and Minerals

of

MANITOBA

PREPARED FOR THE INSTRUCTION AND GUIDANCE OF THOSE PROSPECTING IN MANITOBA

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PREFACE

In the preparation of this book, the reports of the Geological Survey of Canada and of the Mines Branch have been freely drawn upon. Many details have been taken from the publications of the Industrial Development Board of Manitoba and of the Manitoba Department of Mines. These sources and others are acknowledged in their proper places. The author's acknowledgments are also due to the Manitoba Department of Mines for permission to reproduce the sketch maps used to illustrate the text, and to Professor J. S. De Lury, Commissioner of Mines, and Mr. George E. Cole, Chief Inspector of Mines, for valuable suggestions.

Considering the large area of Manitoba still to be explored for minerals, and the great variety of mineral deposits that have been discovered in the Precambrian of Manitoba and other provinces, it has been thought wise to include in the descriptions of valuable minerals many that have not so far been discovered in Manitoba. The wider the knowledge of such minerals the more likely is the prospector to take notice of them.

Gardenvale, P. Q.,
May 27th., 1930.

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Geology and Minerals of Manitoba

CHAPTER I

MINERALS, ROCKS, ORES, MINERAL DEPOSITS

INTRODUCTION

In the reports of the Manitoba Department of Mines and of the Geological Survey of Canada, there is a large amount of information about geology and mineral deposits. In addition to these sources, special reports have been published by the Mines Branch, Ottawa, on certain kinds of mineral deposits such as mica, feldspar, barite, iron ores, etc. This book is an attempt to assemble all such information insofar as it may have a bearing upon mineral development, and to state it in such terms that it will be readily available for prospectors and others interested in the search for and development of mineral deposits in this province. To make the special information more easily intelligible to readers who have no technical education, a few pages are given to short descriptions of minerals, rocks, geological formations, and mineral deposits.

MINERALS

Any distinct substance found in the earth's crust is called a mineral, whether it has any value or not. Valuable mineral deposits may be composed altogether of one or several valuable minerals, such as a body of pure hematite, or of valuable minerals mixed with others of no value, as gold mixed with quartz, or galena mixed with calcite. Rocks are composed of minerals, mostly of no particular value, called rock-forming minerals.

ROCK-FORMING MINERALS

It will be convenient to describe here a number of minerals that enter into the composition of rocks. Most of them are alike in composition in that they are partly composed of **silica,** the substance of which quartz is completely composed.

Silicates.—Minerals composed partly of silica are called silicates. The rock-forming silicates mostly belong to four families, the **feldspars,** the **mica family,** the **hornblende** or **amphibole family,** and the **pyroxene family.** The **feldspars** are light-colored minerals and also light in weight. They are silicates of alumina, with one or more of potash, soda, and lime. They are often distinguished as potash feldspar, soda feldspar, lime feldspar, soda-lime feldspar, etc., according to their composition. Potash feldspars and soda feldspars are high in silica. Lime feldspars are low in silica. Such well-known rocks as granite and syenite are made up largely of grains of feldspar, mostly of the potash and soda kind. Other rocks such as dia-

base, diorite, and gabbro contain feldspars more sparingly, and the feldspars are largely of the lime variety. The **micas** that enter mostly into the formation of rocks are **biotite** or **black mica**, seen as black specks in ordinary granite, and **white mica** or **muscovite**, which is plentiful in some varieties of granite. A third member of the family, **phlogopite** or **amber mica**, is found mostly in crystalline limestone. **Sericite** is a variety of white mica. The **hornblende** family includes minerals that are heavier than the feldspars and mostly black or dark in color. They are silicates of magnesia, etc., with generally a considerable proportion of iron, which accounts for their weight and dark color. Hornblende is the principal constituent of the rock, diorite, and often occurs as part of granite and syenite. The **pyroxene** family resembles the hornblende family in composition and appearance. The rocks diabase and gabbro are made up largely of varieties of pyroxene, which accounts for the usual dark color and the weight of these rocks.

In addition to these families of rock-forming silicates, there are other silicates less common but found plentifully enough to merit mention. **Garnets** are often seen as constituents of rocks that have undergone radical changes after being formed (metamorphic rocks). There are several rocks (dunite, peridotite, etc.,) composed more or less of the green mineral **olivine**, a silicate of magnesia and iron. **Epidote** is a greenish-yellow silicate of alumina, iron, lime, etc. It is apt to be seen near places where igneous rocks have altered the rocks through which they have broken. Its bright color often makes it conspicuous at these con-

tacts. **Chlorite**, is a soft silicate, usually of a greenish color, and in thin scales like mica. It is found in metamorphic rocks, such as chlorite schist, and it is also common in mineral deposits. **Talc** is a silicate of magnesia with water. It is soft and feels soapy when rubbed. Impure talc is often called soapstone, which sometimes forms extensive masses of rock. Talc forms the greater part of the rock talc schist. **Serpentine** is also a silicate of magnesia with water. It is a good deal like talc but harder. It often has a waxy look. Chlorite, talc, and serpentine are **secondary minerals**. They have been made out of other minerals such as pyroxene, hornblende, and olivine, that were there in the first place.

Kaolin.—When feldspars decay under the influence of water, they lose potash, etc., and gain water. The secondary mineral thus formed is called kaolin, or kaolinite. It is silicate of alumina with water. The surfaces of certain rocks are often seen to be covered with a soft layer of this substance, because the feldspar has been kaolinised.

Quartz.—This is a very common mineral forming a considerable part of granite, one of the commonest rocks, and also the main part of common sand and of sandstone. It also forms part of many deposits of valuable minerals. There are a great many varieties of quartz, but in granite it is usually white, light gray, or very pale blue. It is hard enough to scratch steel.

Calcite.—This is the mineral forming the greater part of limestone. It is carbonate of lime, and when strongly heated, as in lime kilns, it loses carbon dioxide, and lime remains. In the ordinary sedimentary

limestone, the characteristics of crystallized calcite are not apparent, but in crystalline limestone, the grains of calcite with their perfect cleavage are easily seen. Calcite often forms part of deposits of valuable minerals, as in some zinc and lead ores. **Dolomite** is carbonate of lime and magnesia. Limestone is often of this composition, and it is then called hard limestone, because dolomite is harder than calcite.

ORES OF METALS

Gold.—The metal itself (native gold) is the form in which the greater part of the gold is found, but there are several minerals called **tellurides** that are compounds of gold and tellurium. Part of the production of gold is as a by--product from copper, zinc, lead, and nickel ores. A good deal of gold is produced from **placer** diggings, where the native gold in the form of nuggets and small flattened grains or scales (gold dust) is found mixed with sand and gravel. Gold placers are formed by the slow decay or breaking up of gold veins, the loosened materials being washed downhill till the heaviest materials come to rest in a hollow. The gold on account of its weight is thus concentrated under the gravel and sand.

Silver.—Native silver has the appearance of commercial silver, but is usually blackened on the surface. **Argentite** is composed of silver and sulphur. It is a black mineral, very heavy and soft. It can be cut like lead. **Proustite** or **light red silver ore** is composed of silver, arsenic, and sulphur. It is of a bright red color.

Pyrargyrite, or **dark red silver** ore, is **dark** red or nearly black. It is composed of silver, antimony and sulphur. **Dyscrasite** is a heavy gray mineral composed of silver and antimony. **Cerargyrite,** or **horn silver,** is a pearl gray mineral that tarnishes to a purple brown color. It is soft and cuts like horn. A good deal of silver is obtained as a by-product in the smelting and refining of ores of lead, zinc, and copper.

Copper.—The metal itself is found in nature (native copper), and important amounts have been produced as native copper. The commonest ore is **chalcopyrite,** or **copper pyrites,** composed of copper, iron, and sulphur, about one third of each. It sometimes carries gold and silver. It is a golden yellow mineral softer than steel. It grinds to a nearly black powder. When the mineral weathers, the presence of iron is shown by the rust that is left. **Chalcocite** is a soft gray mineral composed of copper and sulphur. It contains nearly 80% of copper. It sometimes carries gold and silver. **Tetrahedrite,** or **gray copper ore,** is similar to chalcocite in appearance. It is composed of copper, antimony, and sulphur. It sometimes carries silver or mercury. **Bornite,** or **peacock copper ore,** is composed of copper, iron, and sulphur. The copper varies from 44% to 71%. Bornite is of a coppery brown color, but the surface is usually tarnished to a variety of brilliant colors, green, blue, red, etc. Where copper minerals have weathered, there is often a green stain (**malachite**) or a blue stain (**azurite**). These are carbonates of copper. They are sometimes formed in considerable quantities.

Nickel.—The principal ore of nickel is **pyrrhotite,**

a heavy, bronze-yellow mineral, composed essentially of iron and sulphur, but sometimes with enough nickel to make it a nickel ore. Oftener than not it has no appreciable quantity of nickel. In the Sudbury region, Ontario, the pyrrhotite is mixed with small quantities of **pentlandite** (a sulphide of nickel and iron) and **polydymite** (a sulphide of nickel). A sulphide is a mineral composed of sulphur and a metal. **Millerite** is a sulphide of nickel. It is nearly the same color as copper pyrites. **Niccolite** is a hard, heavy, copper-colored mineral composed of nickel and arsenic. It is often found in the silver veins of the Cobalt area, Ontario.

Cobalt.—A good deal of this metal and its oxide are produced as by-products of the silver mines of Ontario. The principal ore of cobalt is **smaltite,** a heavy, hard, gray mineral composed of cobalt and arsenic. There are several other cobalt minerals found in the silver veins. On weathering they form **erythrite,** a pink mineral, the "cobalt bloom" of the prospector.

Zinc.—Zinc blende or **sphalerite,** is the principal ore of zinc. It is sulphide of zinc, and the pure mineral contains about 67% of zinc. The ore is commonly black, and miners often call it **black jack.** It turns brown when powdered. The purest varieties look much like rosin. Zinc blende sometimes carries important quantities of silver and gold. This is more apt to occur with the black jack than with the light-colored varieties.

Lead.—Galena is the common ore of lead. It is a heavy, soft, lead-gray mineral, composed of lead and sulphur. By weathering it forms **cerussite** (carbonate

of lead), and **anglesite** (sulphate of lead), heavy, soft, white minerals. Galena often carries important quantities of silver.

Arsenic.—The white powder known commonly as arsenic is composed of oxygen and a gray metallic-looking substance, properly called arsenic. Both arsenic and its oxide, white arsenic, are articles of commerce. The chief ore is **mispickel** or **arsenopyrite**, composed of iron, sulphur, and arsenic. It is a hard, heavy, gray mineral much resembling smaltite. Arsenic minerals are often classed as **arsenides.** Many of the minerals of the Cobalt silver ores belong to this class. In the smelting of these ores, arsenic is produced as a by-product.

Antimony.—The chief ore of antimony is **stibnite,** a heavy, soft, gray mineral, composed of antimony and sulphur. It contains nearly 72% of antimony. It sometimes carries important quantities of gold. **Native antimony** is a heavy substance of a tin-white color, and not very hard.

Tin.—**Cassiterite** or **tinstone** is the chief ore of tin. It is a very heavy, hard mineral, usually black, but sometimes brown or dull gray. It is composed of tin and oxygen. Most of the world's supply of tin ore is from placer diggings.

Iron—Hematite is the most important ore of iron. It varies a great deal in appearance. The pure crystallized mineral is heavy, hard, and from gray to nearly black in color. When powdered finely, it turns red. Some bodies of hematite are soft and red, because they are really a compacted powder. The pure mineral contains 70% iron, the rest being oxygen. **Magnetite**

is another oxide of iron. It is notable among minerals for its magnetic property. It is hard, heavy, black, and forms a black powder. The pure mineral has 72.4% iron. **Limonite** is a heavy brown mineral, sometimes soft and looking like iron rust, sometimes hard and darker brown. It is composed of iron, oxygen, and water. The pure mineral contains nearly 60% iron. **Siderite** is carbonate of iron containing about 48% iron. It is light gray to brownish in color. It often looks a good deal like calcite, but is harder and heavier.

Aluminum.—The only ore of aluminum at present in use is **bauxite**, composed of aluminum, oxygen and water. It is somewhat like clay in appearance. It is found mostly in superficial deposits.

Manganese.—**Pyrolusite** is the common ore of manganese. It is a soft, black mineral, composed of manganese and oxygen. **Psilomelane**, or **hard manganese ore** is not so common. Manganese is important in steel manufacture.

Chromium.—**Chromite**, the only ore of chromium, is a hard, heavy, black mineral, somewhat like magnetite, but powdered chromite is brown, while magnetite gives a black powder. Chromite is composed of iron, chromium, and oxygen. Chromium is used in the manufacture of chromium steel and stellite. A number of paints and chemicals are manufactured from chromite.

Titanium.—The chief ores of titanium are **rutile** and **ilmenite**. Titanium has not come into use as a metal, but an alloy, **ferro-titanium**, has been extensively used as a purifier of steel. There are a number of titanium

compounds of growing importance commercially. **Rutile** is titanium oxide. It is a hard, red, or reddish brown, rather heavy, mineral. **Ilmenite** is black and much like magnetite in appearance, but it is not so strongly attracted by a magnet.

Tungsten.—Wolframite is composed of iron, manganese, tungsten, and oxygen. It is black or brownish black and turns red-brown when powdered. It is hard and heavy. **Scheelite** is usually white, yellowish, or pale brown. It is not so heavy or so hard as wolframite. In composition it is tungstate of lime. A third mineral, **tungstite,** is formed by the weathering of wolframite and scheelite. It is of a golden or canary yellow color. There is demand for tungsten ores to make tungsten steel, filaments for electric lights and several other products.

Molybdenum.—The chief ore is **molybdenite,** composed of molybdenum and sulphur. It is a soft mineral much like graphite, from which it can be distinguished by its weight and by the greenish tint of a mark made on white paper and rubbed until it is spread out very thin. The ore is in demand for making molybdenum steel and other alloys.

Uranium and Radium.—The commonest ore of these two metals is **pitchblende,** a very heavy, hard mineral, pitch-black, greenish black or brown black, turning greenish or brown when finely powdered.

Vanadium.—The ores of vanadium are **patronite,** composed of vanadium and sulphur, **carnotite,** which is also an ore of uranium and radium, and **roscoelite, or vanadium mica.** Patronite is found in mineral pitch in Peru. The ash of coal and bitumen is sometimes

rich in vanadium. Carnotite is a canary yellow mineral sometimes found as a crust on ilmenite. Ilmenite generally contains a small percentage of vanadium. Vanadium ores are in demand for the manufacture of vanadium steel.

OTHER VALUABLE MINERALS

Pyrite.—Often called **iron pyrites**. It is a heavy, hard, golden yellow mineral composed of iron and sulphur. It is valuable because of the sulphur of which the pure mineral contains over 53%. It easily strikes fire with steel.

Graphite.—This is a form of carbon. It can be made artificially from coke. The natural substance is soft, light, dark gray to nearly black and marks paper. The lead of lead pencils is graphite.

Apatite.—Commonly called **phosphate**. It is phosphate of lime, etc. It is a fairly hard, medium heavy mineral, brown, green or bluish. It is used for making phosphorus and superphosphate.

Mica.—Two varieties of mica are used, **white mica** or **muscovite**, and **amber mica** or **phlogopite**. To be merchantable, mica must be capable of splitting into thin sheets without cracks, crinkles, or spots of hematite or other minerals that may destroy the insulating power for electricity.

Feldspar.—Most commercial feldspar is the variety called microcline, but **orthoclase** and **albite** are used to some extent. Commercial feldspar is found in a variety of granite, called pegmatite.

Fluorspar.—Also called **fluorite**. It is of medium hardness and weight, and somewhat resembles calcite, but is harder. It is often white, but sometimes green, blue or purple. It is used mostly as a flux in steel making, but also as an ingredient of enamels.

Barite.—Sometimes called **barytes**. It is a heavy, soft mineral, and usually white. It is composed of barium, sulphur, and oxygen. Its chemical name is **barium sulphate**. It is used mostly to make white paint.

Celestite.—Somewhat like barite, but commonly has a somewhat fibrous structure. Its chemical name is **strontium sulphate**. It is used as the raw material for making a number of strontium compounds, including strontium nitrate for red fire.

Magnesite.—This is much like calcite, but is harder and a little heavier. Its composition is similar to that of calcite, but with magnesia instead of lime. It is used to make magnesia for the manufacture of magnesia bricks. It is also the starting point in the manufacture of the metal magnesium.

Asbestos.—This is mostly a fibrous kind of serpentine, although fibrous hornblende was the original asbestos. Quebec produces large quantities of asbestos. Ontario has produced a little.

Talc.—This has already been described as a rock-forming mineral.

Cryolite.—This is a mineral of rather unusual composition. Its chemical name is fluoride of sodium and aluminum. It is a soft mineral, not quite so hard as calcite, but a little heavier. It looks rather like quartz but is much softer. Its color is usually white, and it

looks much like ice, particularly when it is wet. Sometimes it is reddish, brownish, or even black. It is found in veins in rocks of the granite species. The only workable deposit so far found is in Greenland. It is used as a flux in the manufacture of aluminum and also as an ingredient of enamels.

Corundum.—This is a very hard, rather heavy mineral, mostly gray, but sometimes blue or red. Emery is impure corundum, and the two are used for the same purposes, as abrasives.

Gypsum.—This soft, white mineral is found in layers among rocks of the sedimentary class. Its chemical name is hydrated sulphate of calcium. Calcium is a metal that with oxygen forms lime. So gypsum is some times called sulphate of lime. When carefully heated it loses water and becomes plaster of Paris, a material of growing importance in the construction of buildings.

Salt.—The chemical name of salt is sodium chloride. **Rock salt** is the name used to distinguish the solid mineral as it is found in layers among sedimentary rocks. It is often found along with gypsum. Both have come from the evaporation of sea water.

ROCKS AND ROCK STRUCTURES

A rock is any important essential part of the earth's crust, as distinguished from veins and other structures that may be looked upon as occasional and subordinate masses in the rocks. But, as is usual with definitions, no sharp line can be drawn between rocks

and these other structures. Rocks are composed of minerals, usually of several, but sometimes of one.

There are three classes of rocks:—

1. Igneous.
2. Sedimentary.
3. Metamorphic.

Igneous rocks are formed by the cooling of hot liquid rock material which is called lava when it comes to the surface, as it does from volcanoes. By the quick cooling of this material very fine-grained or even glassy rocks are formed. This kind of igneous rocks receives the name **volcanic**. Masses of the same materials have in past ages cooled slowly at great depths beneath the surface so as to allow the formation of a coarse-grained structure, such as can be seen in granite. Some of these masses have been exposed by the erosion of the rocks that originally covered them. These igneous rocks formed at great depths are called **plutonic**. Intermediate between volcanic and plutonic rocks are the **porphyries**, in which there was a period of slow cooling with the formation of large grains (crystals), followed by rapid cooling such that the remaining liquid formed a very fine-grained or glassy mass enclosing the larger crystals. Among the igneous rocks there are large differences in the proportion of silica, the substance that forms quartz and in part the silicates. Rocks that have more than 50% of silica are usually called **acid rocks**, while those that have less than 50% are called **basic rocks**. Volcanic rocks are found as lava **flows**, covering other rocks, or as **dikes**, etc., that have formed by the cooling of lava in cracks and other openings near the surface. Plutonic rocks

are often in great masses, sometimes hundreds of miles in extent, and believed to go to great depths **(batholiths)**. They are also seen in dikes and other comparatively small masses. **Sills** are sheets of plutonic rocks lying among the other rocks in a nearly horizontal position. If they were more nearly upright they would be called dikes. **Laccoliths** are masses that have formed where the molten rock has made a large space for itself by pushing upwards and sideways among the other rocks. Dikes, sills, laccoliths, and batholiths are called **intrusions** or **intrusive igneous rocks**, when it can be seen that they have broken into or through the other rocks there before their advent. The majority of mineral deposits are connected with igneous intrusions.

The following tabular statement includes the commoner volcanic and plutonic rocks corresponding to them:—

ACID	
Volcanic	**Plutonic**
Rhyolite	Granite
Trachyte	Syenite
BASIC	
Basalt	Gabbro, Diabase
Andesite	Diorite

Rhyolite is of the same composition as granite, but is too fine grained to show the grains or crystals of quartz, feldspar, and mica visible in granite. Similarly for the other pairs, trachyte and syenite, etc.

Granite is composed of quartz, feldspar and usually mica or hornblende or both of these minerals. **Syenite**

is like granite but it has little or no quartz. **Gabbro** and **diabase** are composed of pyroxene and feldspar. They differ in microscopic structure. **Diorite** is composed of hornblende and feldspar.

Acid rocks such as granite are mostly light-colored and light in weight. Basic rocks, like gabbro and diabase, are mostly dark colored and heavy.

Sedimentary rocks are formed largely of fragments of other and older rocks, but also more or less of materials that have been precipitated from bodies of water and deposited as sediments. To understand sedimentary rocks it is necessary only to think of all the present deposits of loose material, such as sand, gravel, and various kinds of mud and clay lying at the bottom of bodies of water, or spread out on the dry land. The same kinds of collections, consolidated by pressure and cementing material, form the common sedimentary rocks such as sandstone, conglomerate, shale, and limestone. **Sandstone** has been made by the consolidation of beds of sand, **conglomerate** from gravel, **shale** from clay, and **limestone** in part from shells of minute and larger animals and plants, and in part from carbonate of lime precipitated from the water. As the shells are also made mostly of carbonate of lime, the rock as a whole is of that composition. The bodies of plants and animals covered up in the mud and sand of past ages have become **fossils**. It is partly by means of the fossils that geologists are able to determine the relative ages of sedimentary rocks. Where the rocks have not been changed since consolidation by folding or overturning, it is obvious that any layer is younger than the layers beneath it. By study of the fossils in unchanged sedi-

mentary rocks all over the world, a certain succession in the living beings characteristic of each age has been made out. These results are shown in the following table, in which the names of eras and periods are also the names of the rock groups and systems. At the beginning are the unconsolidated materials covering the rocks, mostly the result of glacial action. The loose materials formed since the Great Ice Age are called **Recent**. Next older come the **Glacial** deposits, and so on.

Era or Group		Period or System
Cenozoic	Quaternary or Age of Man.	Recent Glacial (Pleistocene)
	Tertiary or Age of Mammals	Pliocene Miocene Eocene
Mesozoic or Secondary	Age of Reptiles	Cretaceous Jurassic Triassic
Paleozoic or Primary	Age of Amphibians Age of Fishes	Permian Carboniferous Devonian
	Age of Invertebrates	Silurian Ordovician Cambrian
Eozoic or pre-Cambrian	Dawn of Life	Keweenawan Animikean Algoman Timiskamian Laurentian Grenville Keewatin

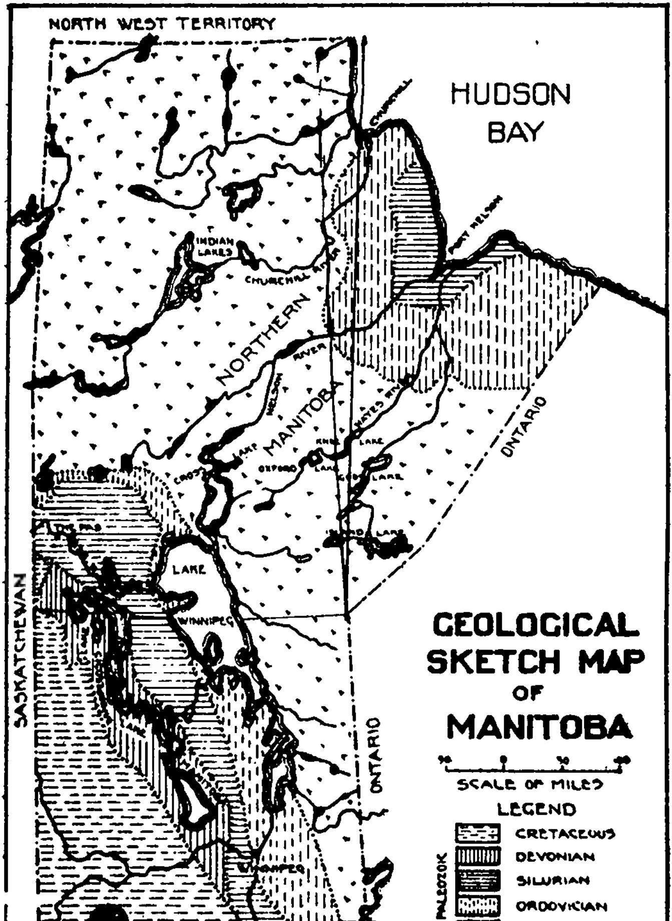
Metamorphic Rocks.—These are rocks formed by the alteration of rocks of the other two classes by heat, pressure, and the action of hot liquids and gases coming from lava or hot igneous rocks. The changes may be more or less complete according to circumstances. Thus shale becomes slate, and by further alteration it is changed to mica schist. The effect of pressure is to develop a layered structure, and when this has gone far enough the layers are very thin, forming a **schist**. There are many kinds of schists. Any rock of the igneous or sedimentary classes may be converted into a schist. In the following table some of the commoner igneous and sedimentary rocks are shown with their metamorphic equivalents:—

Sedimentary	**Metamorphic**
Conglomerate	Gneiss and Schist
Sandstone	Quartzite and Schist
Shale	Slate and Schist
Limestone	Crystalline Limestone
Igneous	**Metamorphic**
Granite	Gneiss
Syenite	Gneiss
Diorite	Gneiss
Rhyolite, etc.	Schists
Peridotite	Serpentine

MINERAL DEPOSITS

By this is meant those concentrations of minerals that have possible commercial value. A great many of these deposits are in the form of veins and other struc-

tures that have originated in connection with intrusions of igneous rocks. Others are sedimentary in origin, and may be found among the layers of sedimentary rocks. Still others have probably been concentrated in cavities in the rocks by the action of circulating water from above. The most important mineral deposits from the point of view of variety and value are those that owe their origin to igneous intrusive rocks. For example, something like 80% of the productive gold mines of the world are closely connected with intrusions of porphyry. Canada is fortunate in having in most of the provinces large areas where igneous intrusions are plentiful.


NORTH WEST TERRITORY
HUDSON BAY
CHURCHILL
PORT NELSON
INDIAN LAKES
CHURCHILL RIVER
NORTHERN MANITOBA
NELSON
RIVER
HAYES RIVER
KNEE LAKE
OXFORD LAKE
GODS LAKE
ISLAND LAKE
LAKE WINNIPEG
WINNIPEG
SASKATCHEWAN
ONTARIO
ONTARIO
UNITED STATES
Eocene
GEOLOGICAL SKETCH MAP OF MANITOBA
SCALE OF MILES
LEGEND
CRETACEOUS
DEVONIAN
SILURIAN
ORDOVICIAN
PRE-CAMBRIAN
PALEOZOIC

CHAPTER II

SKETCH OF THE GEOLOGY OF MANITOBA

INTRODUCTION

The area of the Province of Manitoba is about 254,000 square miles, of which more than three fifths is underlain by Precambrian rocks. The southwest part of the province is underlain by Cretaceous rocks to the extent of about 50,000 square miles with a patch of Eocene about 45 miles long and 15 miles wide along the international boundary south of Boissevain. Between this area and Lake Winnipeg is a broad band of Paleozoic formations about 440 miles long and extending from the United States boundary northward. This area includes rocks of Devonian, Silurian, and Ordovician ages, the rocks occurring in this order from west to east. The northeast part of the province is underlain by Ordovician ond Silurian rocks forming the coast of Hudson Bay from the Ontario boundary to Fort Churchill, and making an area of about 30,000 square miles. Between these two Paleozoic areas, the country is Precambrian, and these older formations extend north and south to the boundaries of the province. The Precambrian of Manitoba is thus con-

tinuous with that of Ontario along the greater part of the interprovincial boundary, and it underlies the whole of the northern part of the province except that part occupied by the Paleozoic around Port Nelson. The east shore of Lake Winnipeg forms the western boundary of the central part of the Precambrian area.

In giving details of the geology of the province, the unconsolidated covering is first referred to as due mostly to glaciation. This is followed by a short description of the rock formations in the order of their age, beginning with the youngest.

Glaciation

During the last glacial age Manitoba was invaded by a glacier having its centre west of Hudson Bay. The movement was mostly from north to south, and glacial débris from the northern Precambrian areas was spread over the Paleozoic and Cretaceous areas of the south. A great glacial lake, Lake Agassiz, covered the whole of the Manitoba lowlands and extended eastward into Ontario and west into Saskatchewan. These events account for the boulders of granite and other rocks different from the solid rock formations above which they are found. In some parts of Southern Manitoba this "drift" rock has been used for building stone. The fertile level plains once formed the bottom of Lake Agassiz.

Eocene

The age relations of Tertiary formations can be seen in the table at p. 17. The Eocene formations represent a period when plant and animal life was taking on the forms characteristic of the present. It

was the dawn of life as it is now. In Manitoba, Eocene formations underlie an area 45 miles long by 15 miles wide south of Boissevain. This area includes Turtle Mountain with its lignite beds. The rocks are shales lying on sandstone that is probably Upper Cretaceous in age.

Cretaceous

Cretaceous formations underlie a triangle the base of which extends from a point a few miles east of Gretna westward along the international boundary to the Saskatchewan line, interrupted south of Boissevain by the 45-mile stretch of Eocene rocks. The Cretaceous beds can be followed northward for more than 300 miles. They consist of white and brown sandstones, sandy shale, and shale with occasional seams or streaks of lignite, the whole series having a combined thickness of 1600 to 1700 feet. They form the Pembina and Tiger hills, Riding and Duck Mountains, and the Pasquia hills.

PALEOZOIC

The subdivisions of the Paleozoic beginning with the youngest are as follows:

Permian	Devonian	Ordovician
Carboniferous	Silurian	Cambrian

No rocks of Cambrian, Carboniferous or Permian periods are known in Manitoba. As the Carboniferous rocks are the oldest in which any considerable quantity of coal has been found, their absence in Manitoba makes it unlikely that important bodies of coal will

be discovered in the Paleozoic of this province. Thin seams of coal have been found in Devonian rocks in Russia, but in older rocks no workable deposits have been found anywhere.

The Paleozoic rocks of Manitoba consist mostly of limestone and shale, with smaller thickness of sandstone. The strata are horizontal or nearly so, indicating little disturbance of the country since it became dry land after the Devonian rocks were deposited. The absence of folding and large igneous intrusions makes it unlikely that these younger rocks will ever contribute much, if anything, to the production of gold, silver, and copper, but lead and a number of non-metallic minerals such as barite and fluorspar may be found. Zinc ore may also occur. Gypsum, salt, petroleum, and natural gas may be found in Paleozoic rocks.

Devonian

This period was named from Devon, England. The Cretaceous layers form an escarpment at the foot of which Devonian rocks appear and extend in an irregular narrow band eastward bounding the Cretaceous triangle throughout the greater part of its length. In the Devonian area lie lakes Manitoba, Dauphin, and part of Winnipegosis. The width of this band is from 25 to 50 miles. It consists of beds of limestone and a little shale aggregating a thickness of about 400 feet. The limestone includes layers of dolomite in the region of Winnipegosis and Manitoba lakes.

Silurian

Silurian, Ordovician, and Cambrian rocks were first studied scientifically in Wales, and the names have

been formed from old Welsh tribal and territorial names. East of the Devonian limestone belt Silurian beds form a band extending from the international boundary northward about 60 miles beyond The Pas, where it expands to a breadth of about 100 miles. The Silurian beds are about 385 feet thick and are mostly limestone (partly dolomite), but near St. Martin lake there are beds of gypsum accounting for a total thickness of 150 feet.

Silurian beds are also found along the Hudson Bay coast east and west of Port Nelson, and extending inland from 25 to 50 miles. The rocks are mostly limestone.

Ordovician

Ordovician beds form the most easterly of the Paleozoic bands. The Ordovician band is about 60 miles wide, and extends from the international boundary to the foot of Lake Winnipeg where it narrows and bends westward to the Saskatchewan boundary. This band includes the western part of the basin of Lake Winnipeg, the eastern shore of which is Precambrian. In the basin of Lake Winnipeg, the Ordovician beds consist of about 300 feet of limestone underlain in most places by sandstone and shale in thickness up to 100 feet and in places covered by shale. These beds lie upon the Precambrian rocks, and the limestone forms a scarp at the foot of which the Precambrian rocks can occasionally be seen. In Southern Manitoba, at Stony Mountain and in other places, hills of Silurian and Ordovician limestones rise from the drift-covered plains.

A second Ordovician area is found south and west of the Hudson Bay Silurian region. It consists of beds of limestone less than 200 feet thick. The northern limit of this area forms Cape Churchill.

PRECAMBRIAN

Rock formations earlier than the Cambrian are grouped as Pre-Cambrian. The Precambrian of Manitoba is continuous from the international boundary where it forms the western shore of the Lake of the Woods to the northern boundary of the province at the 64th parallel of latitude. At its southern end this area is only a few miles wide, but at its northern end it occupies the full breadth of the province from Hudson Bay to longitude 102° west, a distance of 260 miles, constituting more than three fifths of the area of Manitoba. The greater part of this large area is mapped as "Precambrian, unclassified (chiefly granite and granite-gneiss)." This uniformity is relieved at a number of places by patches of "Early Precambrian (includes Timiskamian, Keewatin, and other strata supposedly older than Huronian)," the association of rocks in which have been found most of the productive gold deposits in the adjoining province of Ontaro. In the extreme south of Manitoba, the gold-bearing formations of the Lake of the Woods in Ontario are continued westward into Manitoba for a few miles. Other patches of these formations cross the boundary along the English and Oiseau rivers. Farther north, about half way between Victoria Beach and The Narrows, a strip of these early Precambrian rocks stretches from Lake Winnipeg to and across the On-

tario boundary. This patch is in line with the Red Lake gold area in Ontario. Considerable areas of these old Precambrian rocks are found along the northern edge of the Paleozoic. This is the region that includes the Flin Flon and Sherritt-Gordon mines. The formations at the latter are thought to be Grenville in age. East of this area are a number of patches of early Precambrian around Cross Lake, Oxford Lake, God's Lake, and Island Lake. A narrow strip follows the course of the Burntwood River, a branch of the Nelson River. All these early Precambrian areas have been shown to be mineral-bearing. As detailed exploration goes on, other areas of these favorable rocks are being found farther north.

In describing the formations of the Precambrian periods, it may be well to set down as a basis a tabular statement for the corresponding regions in Ontario and Quebec where the age relations and subdivisions have been more completely worked out than has been possible in the comparatively short time during which attention has been given to Manitoba.

PRECAMBRIAN

Period	**Events**
Keweenawan	Intrusion of gabbro, diabase, and more acid rocks. Deposition of Sudbury copper-nickel ores, cobalt-silver ores, lead-zinc ores, and gold ores. Sedimentary rocks deposited.
	Deposition of Cobalt sedimentary rocks, the sedimentary series of

Animikean	the Sudbury basin, the Animikie series of Thunder Bay, and of iron formation.
Algoman	Intrusion of granite, etc. Deposition of gold ores in many parts of Ontario, Quebec and Manitoba.
Haileyburian	Intrusion of gabbro, etc., and deposition of nickel and gold ores.
Timiskamian	Deposition of Timiskamian sedimentary rocks, also probably Doré, Sudbury, and Hastings series.
Laurentian	Intrusion of granite, etc., with probable deposition of ores since destroyed by erosion.
Grenville and Keewatin	Deposition of Grenville limestone, etc. Extensive banded iron formation. Extensive lava flows.

In studying this table it is better to begin at the bottom so as to follow the events in the order in which they took place. It is seen that periods of sedimentation alternate with periods of igneous intrusion and ore deposition. Thus, following the formation of the Keewatin and Grenville rocks came a period of mountain-building accompanied by the intrusion of vast masses of Laurentian granite, etc. Doubtless at this time there was extensive deposition of ores, but the deep erosion and other changes that followed have destroyed at least the majority of these. Then came

another period of sedimentation, with the laying down of the Timiskamian and other series. This was followed by a second time of mountain building with intrusion, first of Haileyburian basic rocks and then of Algoman granite, etc. The Haileyburian basic rocks brought nickel ore and perhaps copper ore. The Algoman intrusion was followed by the deposition of gold and other ores very widely throughout the Precambrian. Fortunately the subsequent erosion of these mountains went deep enough to uncover the ore bodies without completely removing them. Then came a third period of sedimentation which formed the Animikean rocks, including in Ontario the Cobalt series, the sedimentary rocks of the Sudbury copper-nickel basin, and those of the Thunder Bay silver area. Next came the Keweenawan period of folding with intrusion of gabbro, diabase, etc., and formation of silver ore bodies in the Cobalt and neighboring areas, and in the silver area at the west end of Lake Superior. At this time also there were formed the Sudbury copper-nickel ore-bodies and copper ore-bodies in other parts of the province. Zinc and lead ore deposits seem to have originated both in the Algoman and in the Keweenawan periods. As the ores of these two metals have also been found in Paleozoic rocks, their deposition covered a very wide range of time. The geological survey of Manitoba is still too incomplete to determine how many of these periods of mountain building, erosion, and sedimentation occurred in this province, but the general resemblance to the geology of the neighboring province of Ontario is apparent.

The key to an understanding of the present Precambrian rock surface of Manitoba with its mineral deposits is to be found in these alternate foldings into mountain ranges followed by erosion and the spreading out of the débris to form sedimentary rocks. The cores of the mountains were granite with smaller bodies of other igneous rocks. These rocks gave rise to the mineral deposits, which were mostly formed at considerable depths below the surface. Erosion levelled the mountains and at the same time lowered the general surface so as to lay bare many of the mineral deposits. Others were partly removed and doubtless many were completely destroyed. The valuable deposits of metal ores must be looked for mostly, not in the granite, but outside of it in the older rocks.

There are large areas of granite and gneiss representing the cores of the ancient mountains. These are surrounded by remnants of the older rocks that once formed a more or less complete covering over mountains and valleys. As these processes of folding, erosion, and sedimentation have been repeated a number of times, the final result is a very complex mixture of rocks. The chief periods of erosion were very long, allowing time for pretty complete levelling of the mountains. This accounts for the large size of the granite and gneiss areas.

The direction of these ancient mountain ranges is preserved in long lines of contact between the granite and the remnants of the rocks that once formed the outer shell of the mountains, or of rocks that were laid down as sediments against their flanks. From this and other evidence it can be judged that the gen-

eral direction of the mountain ranges was roughly northeast-southwest. This is also a very common direction (strike) for veins and other deposits of minerals. It is also the commonest direction in which the layers of schists lie. These phenomena are connected. The mountain-building developed weak places in the rocky structure. sometimes breaks running for miles, sometimes bands of shattered rock (shear zones and crush zones) and sometimes the weak structure in thin sheets characteristic of schists. These weak places were the most favorable for the entrance of the valuable minerals concentrated out of the granite and other rocks while they were in the liquid state. This explains the occurrence of mineral deposits in ranges that so often have the northeast-southwest direction. It follows that the search for minerals in Manitoba should be directed along the outskirts of the granite areas and not within those areas. But the Province is by no means completely mapped geologically. It may happen that a large space set down as one mass of granite really consists of several masses with other rocks between.

PRECAMBRIAN ROCKS

It may be useful to give a short description of the character and distribution of Precambrian rocks in Manitoba, beginning with the oldest.

Keewatin

The rocks of this system are mostly volcanic in origin, lava flows of various kinds, many of them bas-

ic and others acid in composition. The basic lavas often show the pillow structure. It gets its name from its resemblance to pillows pressed together. Sometimes the form of the bunches suggests crowded snowshoe tracks. Pillow lava is supposed to have been formed under water. The lavas have been more or less completely converted into schists, the basic lavas having developed chlorite, while the alteration of the acid lavas has formed sericite. Banded iron formation, consisting of quartz, magnetite, hematite, and sometimes siderite and pyrite variously mixed and more or less banded, is occasionally seen, as at Knee Lake.

With the Keewatin lavas are associated sedimentary rocks the age of which is uncertain, but some of them are apparently older than the lavas.

As the Keewatin rocks are the oldest, they have passed through all the alterations of mountain-building with accompanying mineral deposition, of erosion, and of sedimentation. One consequence is that the lava flows are found in folds eroded so as to show their edges. Another is that sedimentary rocks, originally laid down on top of the lava flows, but afterwards folded with them into mountains which were later eroded, now show the edges of the strata beside those of the lava flows. A third consequence is that the Keewatin rocks, because of the weakness of their structure and also because, being the oldest, they have had all the chances of receiving mineral deposits, are the most productive. Experience shows that the best prospecting ground is where there are large areas of Keewatin rocks broken into by comparatively small

intrusions of granite, acid porphyry, diabase and other igneous rocks.

Grenville

This series of sedimentary rocks is more plentiful and more definitely known farther east than in Manitoba. It is thought that the gneiss and schists with which the Sherritt-Gordon ore deposits are associated may be of Grenville age, and crystalline limestone occurs farther west. The series as seen in Ontario and Quebec consists of crystalline limestone, iron formation, slate, quartzite, and graywacké. These rocks have suffered a great deal of alteration and have been largely changed into various kinds of schists and sometimes to gneiss.

Laurentian

After the deposition of the Grenville sedimentary rocks upon the Keewatin lavas, etc., both series of rocks were invaded by great masses of granite and syenite, since largely converted into gneiss. Large areas shown on the older geological maps as "Laurentian granite and gneiss" are lately shown as "unclassified, mostly granite and gneiss." This means that the age-relations have not been made out with certainty. It has been found that part, perhaps most, of the granite is younger, probably of Algoman age. As the survey goes on, patches of other rocks are found within those areas formerly colored uniformly as Laurentian. It is important to know this, since the Laurentian granite and gneiss have not proved to be very productive of minerals.

Timiskamian, etc.

The Timiskamian series of sedimentary rocks as found in Ontario and Quebec consists usually of a basal conglomerate, followed by quartzite, graywacké, and slate. Similar rocks in Manitoba may be of the same age. As these rocks have shared in the ancient folding and have been invaded by intrusions of granite and other plutonic rocks, they are usually tilted to a high angle and are often much metamorphosed.

Algoman

This name is applied to intrusions of granite, syenite, acid porphyries, gabbro and lamprophyre etc., that are closely connected with deposits of gold ore and other important mineral deposits. Most of the granite of northern Manitoba may be of this age. It is ordinarily biotite or hornblende granite.

Animikie, Cobalt, etc.

This series of sedimentary rocks has not been definitely found in Manitoba.

Keweenawan

These are the youngest Precambrian rocks. They include a sedimentary series not so far identified in Manitoba, and, more important, the basic intrusives and lava flows of the period, one of great igneous activity accompanied by deposition in Ontario of silver, copper, nickel and other ores. In some parts of Manitoba, for example, in the Cross Lake region, there are numerous diabase dikes that may be of Keweenawan age.

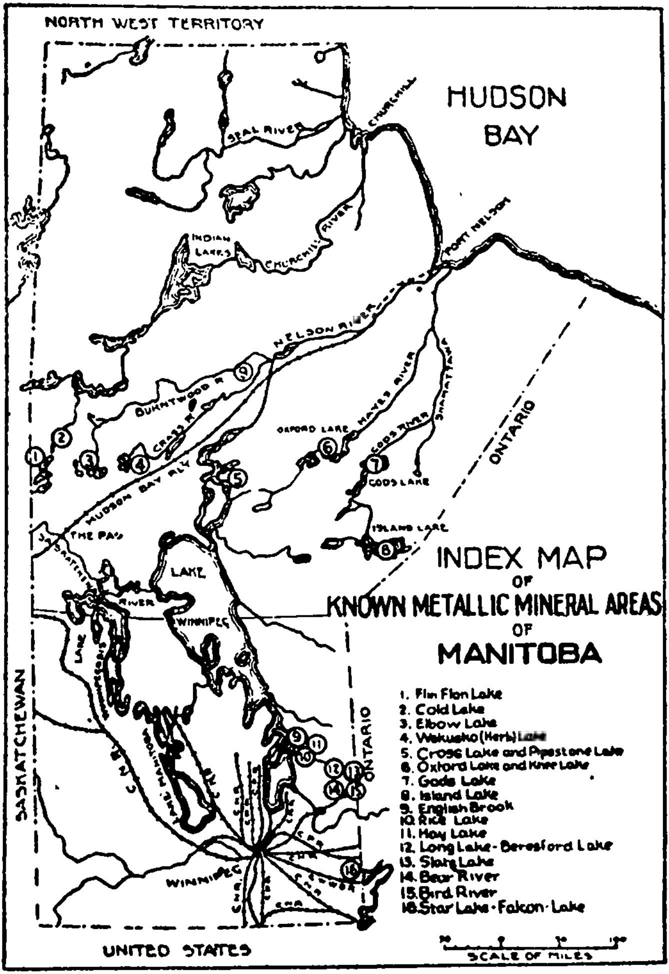
CHAPTER III

METALLIC MINERALS

GOLD, SILVER, PLATINUM

The mineral production of Manitoba has so far been characterized by some diversity, but the geology of the province leads to the expectation that diversity will be increased by the discovery of economic minerals not hitherto produced. This expectation is justified by the development of the copper-zinc deposits in Northern Manitoba, and the discovery of tin and lithium, antimony, and other ores.

In describing the mineral deposits of the province, they are divided into two classes (1) **metallic** and (2) **non-metallic**. Metals and ores of metals are put in the metallic division, and minerals not used as ores of metals, in the non-metallic, even though the properties of the minerals themselves may be metallic. For example, pyrite is described in the non-metallic class, because its use as a source of sulphur puts it there, although it has the metallic appearance and contains a metal, iron. The ores of a metal are described under the heading of the metal, as, for example, hematite, magnetite, limonite, and siderite under the heading **Iron**.


NORTH WEST TERRITORY
HUDSON BAY
SEAL RIVER
CHURCHILL
INDIAN LAKES
CHURCHILL RIVER
PORT NELSON
NELSON RIVER
BURNTWOOD R
GRASS R
OXFORD LAKE
HAYES RIVER
GODS RIVER
GODS LAKE
ISLAND LAKE
HUDSON BAY RLY
THE PAS
RIVER
LAKE
WINNIPEG
ONTARIO
SASKATCHEWAN
C.N.R.
C.P.R.
WINNIPEG
UNITED STATES
SCALE OF MILES
INDEX MAP
OF
KNOWN METALLIC MINERAL AREAS
OF
MANITOBA
1. Flin Flon Lake
2. Cold Lake
3. Elbow Lake
4. Wekusko (Herb) Lake
5. Cross Lake and Pipestone Lake
6. Oxford Lake and Knee Lake
7. Gods Lake
8. Island Lake
9. English Brook
10. Rice Lake
11. Hay Lake
12. Long Lake - Beresford Lake
13. Slate Lake
14. Bear River
15. Bird River
16. Star Lake - Falcon Lake

The precious metals, gold and silver, are taken first, and with them the rare and very valuable metals of the platinum group. The order after that is roughly the order of importance in production of metals, actual and possible. Ores are described that under present circumstances are not being used. The circumstances may change and bring them into use. Ores not yet discovered in Manitoba are referred to when the geology of the province is favorable for their occurrence.

GOLD

Gold Epochs

Judging from Ontario, where the geology of the gold fields has been worked out in greatest detail there were probably four epochs of gold deposition in Precambrian rocks. To begin with the oldest, doubtless the extensive intrusion of **Laurentian** granite and other igneous rocks into the Keewatin and Grenville formations led to the deposition of gold, but the erosion of succeeding ages has removed most, if not all of them. The erosion of the Laurentian mountains must have formed extensive and widespread gold placers, but these along with others formed in subsequent periods have been scattered by glacial action. Some of them may possibly have been preserved as conglomerate rock. Some less important gold deposits seem to have been formed in connection with intrusions of basic rocks of **Haileyburian** age, younger than the Laurentian but older than the Algoman intrusives. The gold deposits so far discovered in Manitoba are associated with intrusive granite, etc., of an age

thought to be the same as that of the **Algoman** intrusives of the Ontario gold fields farther east. Masses of granite, syenite and porphyry have broken through the Keewatin greenstone, schists, etc., and the Timiskamian conglomerate, slate, quartzite and graywacké. The fourth epoch of gold deposition is the **Keweenawan**. The gold deposits associated in Ontario with the intrusives of this period are small and none of them are now productive. The veins are mostly in close association with dikes and other masses of diabase, gabbro, etc., that have broken through sedimentary rocks of Animikean (Cobalt) age and therefore must be younger than these.

It is at once obvious that the Algoman epoch of gold deposition exceeds all the others in importance, and prospecting for gold should therefore be directed to those areas where assemblages of Keewatin lavas, greenstones and schists, Grenville gneiss, schists, etc., and Timiskamian conglomerate, slate, etc., have been intruded by granite, syenite, and especially porphyry. The important gold ranges are commonly indicated by long, narrow strips of Timiskamian sedimentary rocks, which are the remains of those rocks that once formed the outer shell of mountains ranging between east and west, and northeast-southwest. The removal of these mountains laid bare the mineral deposits that had been formed deep down beneath their flanks. This denudation left the Timiskamian sedimentary rocks and the underlying Keewatin lavas and schists lying side by side representing the lower parts of the folds. It follows that a gold discovery can often be repeated many times by following these elongated

structures in an easterly or westerly direction. The best prospecting ground is found around the smaller masses of granite, syenite, and porphyry, rather than in the neighborhood of the masses that extend unbroken for many miles. Erosion has removed the deposits that may have gathered at the tops of these larger bodies, but has been less severe over the places where the smaller patches show. But long tongues of granite, etc., projecting from the main body, may be favorable. The veins and shear zones that may carry gold most commonly follow the general strike of the country, shown by long narrow bands of rocks, ridges, long lakes, and other features of the surface. There is often a well marked line of break running for miles in a definite direction, and the veins are apt to follow this line.

Types of Gold Deposits

According to the metallic minerals accompanying the gold and the nature of the gangue minerals, gold deposits may be classified into the following types:

1. **The pyrite-gold-quartz type** in which the chief metallic mineral is pyrite and the main gangue mineral is quartz. With the pyrite there may be smaller quantities of copper pyrites, zinc blende, galena, pyrrhotite, magnetite, mispickel, bismuth minerals, tellurides, molybdenite, scheelite, native copper, etc., and the gangue minerals may be represented in small part by calcite, barite, tourmaline, feldspar, etc. The gold usually occurs with finely divided pyrite, calcite, and chlorite in thin cracks in the quartz, and with small

grains of pyrite in the schist. This is the commonest and most productive type.

2. **The mispickel-gold-quartz type** in which the chief metallic mineral is mispickel. Many of the gold deposits of the Herb Lake area are of this type.

3. **The gold-tellurides type** in which the gold is accompanied by tellurides, a family of minerals composed of tellurium combined with certain metals. Some of them are tellurides of gold or of gold and silver, and their presence increases the gold values in the ores. It at the same time causes some difficulty in extracting the whole of the gold.

4. **Gold-calcite type** includes deposits in which calcite is the principal gangue mineral. There may be small quantities of quartz, and the metallic minerals may be represented by pyrite, copper pyrites, galena, zinc blende, etc.

5. **Copper-gold type,** represented by the Flin Flon mine and other ore bodies of the Northern Manitoba district.

Gold deposits can be classified according to shape and relation to surrounding rock.

1. **True fissure or simple vein** is a body of ore filling a single, long, narrow space, the well-defined walls of which are approximately parallel. Such veins are apt to occur in compact rocks rather than in those that have been weakened by compression into schists.

2. **Composite veins or lodes.** These are made up of a number of nearly parallel lenses of ore more or less connected by cross veins, the rock between being often partly converted into ore. The number of veins is

sometimes very large, taking in a wide space and great length.

3. **Sheeted zones.** A large number of very narrow parallel veins or veinlets closely spaced.

4. **Stockwork.** Stringers of ore irregularly placed in the rock, more or less like a net-work. Apt to occur in the more compact rocks like granite, porphyry, dolomite, and ankerite.

5. **Fahlbands or Shear zones.** These are bands or zones of rock that have been shattered and squeezed so as to be more or less converted into schists. The crevices are filled with pyrite and other sulphides, and there may be very little quartz. These bands are sometimes very wide, but payable gold ore is usually restricted to parts of them.

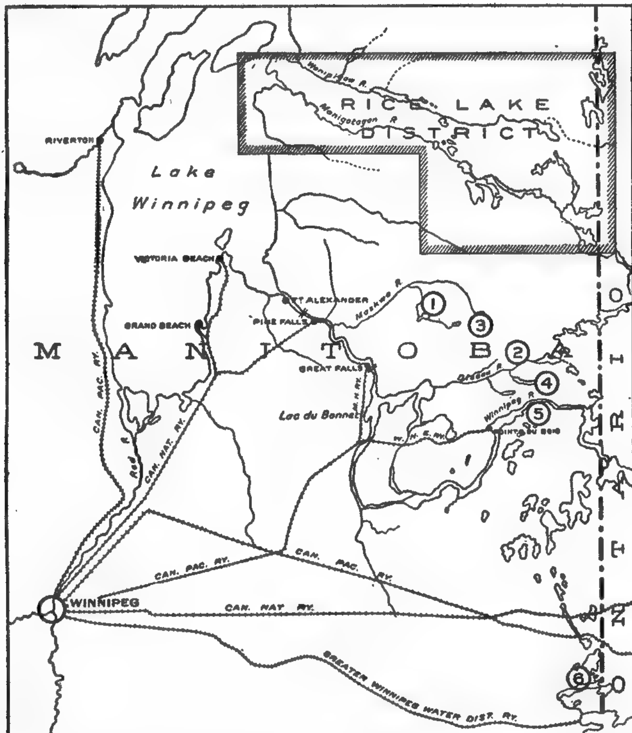
6. **Single lens or pipe.** This is a body that has little length in proportion to its width and depth.

Pay Shoot

In gold deposits the gold content may vary in the same ore body. This variation often occurs in such a way as to form a rich zone descending vertically or with a slope (pitch). This rich part of the vein or other deposit is called the **pay shoot.**

Rocks in which gold deposits are found

The most productive deposits are in Keewatin schists and Timiskamian sedimentary rocks in the neighborhood of intrusions of porphyry, granite, and syenite of Algoman age. Some gold has been produced from veins in granite and syenite.



INDEX MAP OF SOUTHEASTERN MANITOBA

Scale of Miles

0 5 10 15 20 25 30 35 40 45 50

LEGEND

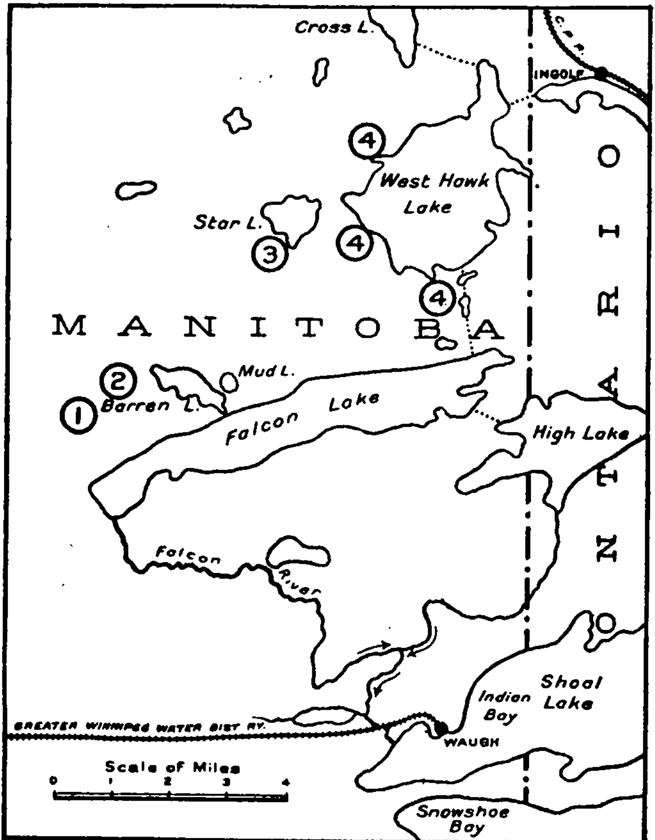
(1) *Maskwa River Copper-Nickel*
(2) *Oiseau River Copper-Nickel*
(3) *Cat Lake Lithium Dep*
(4) *Bernic Lake Lithium Dep*
(5) *Winnipeg River Lithium Dep*
(6) *Boundary Dist.*

Southeastern Manitoba

THE BOUNDARY DISTRICT

The formations characteristic of the Lake of the Woods goldfields of Ontario continue westward into Manitoba. Shoal Lake, which empties into Lake of the Woods, is partly in Manitoba, and the country for about ten miles north of Shoal Lake has been prospected from the Ontario boundary westward for 8 or 10 miles between the main line of the Canadian Pacific railway and the Greater Winnipeg Water District railway. In this area, discoveries have been made in the neighborhood of Falcon, West Hawk, and Star lakes, the most interesting being those around Star Lake. The early discoveries were made in a mineralized belt south and west of Star Lake and extending north and east to and beyond the Canadian Pacific railway. Keewatin volcanic rocks partly converted into schists are folded with conglomerate forming a narrow belt flanked on both sides by large areas of granite that intrudes both the volcanics and the conglomerate. Smaller intrusions of granite occur. The gold has been found in quartz veins both in the granite and in the intruded rocks, and also in shear zones with quartz and sulphides. In the latter occurrences, the gold is mostly in the sulphides. Most of the gold-quartz veins are grouped around a boss of syenite that outcrops south of Star Lake, and the veins occur both in the syenite and in the schist that surrounds it.

Of the 10 or 12 claims on which some development work has been done, a few are described here.



SKETCH MAP OF BOUNDARY DISTRICT

LEGEND

(1) *Molybdenite Deposits* (3) *Gold Deposits*

(2) *Tungsten Deposits* (4) *Sulphide Deposits*

The **Penniac Gold Reef** is three quarters of a mile southwest of Star Lake. The ore body is a shear zone in schist with small quartz veins. This zone is near the contact of a granite mass with conglomerate. The quartz carries small quantities of pyrite, pyrrhotite, mispickel, and free gold. A shaft has been sunk, some drifting done, a small stamp mill built, and a small quantity of bullion produced. An outcrop of quartz about a quarter of a mile south of the shaft is thought to be a continuation of the vein. The ore seems to be low grade.

The **Sunbeam** claims are east of the Penniac. A dike of hornblende syenite intrudes an older granite. Both are mineralized with pyrite, bornite, and copper pyrites. The fractured rock is cemented with veinlets of quartz mineralized with pyrite, galena, and zinc blende. Channel samples of the mineralized rock have shown only a trace of gold, but a sample from an 8-foot pit gave $55 a ton.

The **Waverley** claim is one mile south of Star Lake. The gold is found in a shear zone and in narrow veins of milky quartz that do not exceed 4 feet in width. This zone is in the syenite not far from its edge. The minerals accompanying the gold are pyrite and mispickel. Samples have shown values of $16 and $29.60 a ton, the former from the quartz and the latter from the sheared rock.

The **Gold Coin** adjoins the Waverley on the north. A shear zone in the syenite carries a small quartz vein the width of which is not more than 3 feet. Vein and wall rock are mineralized with pyrite and mispickel.

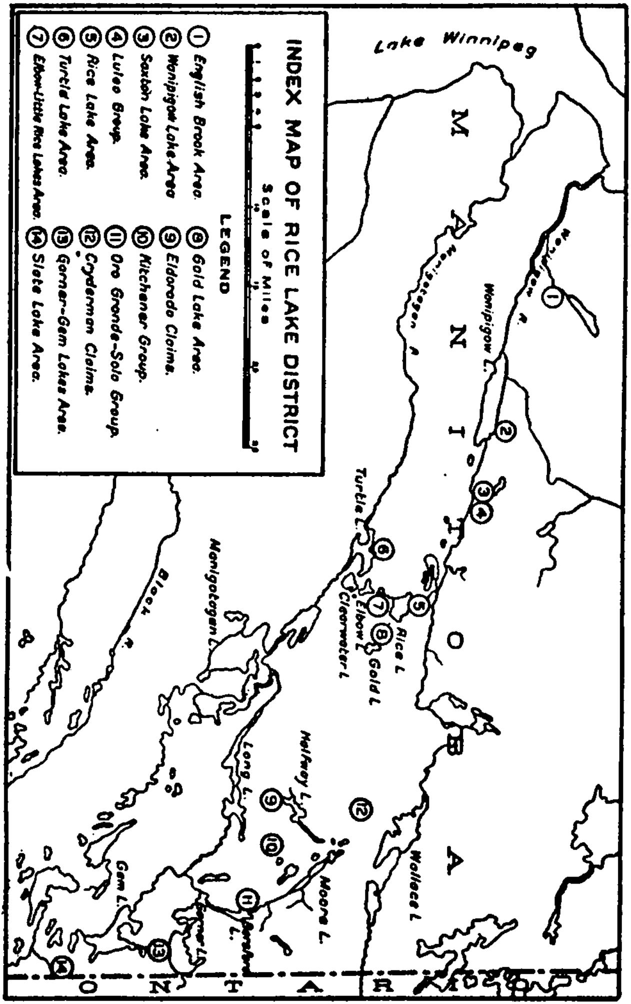
A selected sample assayed $55 a ton, but a channel sample from the quartz showed only $1.60.

Samples taken by E. L. Bruce in 1918 from the old dumps at some of the other mines gave high assays. Two from the **Enterprise** dump assayed $1.60 and $32.80. One sample from the **Boyes** dump gave $48.40. The Boyes claim is near the northwest end of Barren Lake. The gold is in narrow quartz veins in schist not far from the contact with the syenite boss. The associated minerals are mispickel and pyrite. Channel samples from some of the other properties showed no gold.

The work so far done in the Boundary District has not resulted in a gold-mining industry. The information accumulated points to the existence of a large number of small veins with high gold values in places. It is possible that systematic prospecting may result in the discovery of larger deposits with more consistent values.

RICE LAKE DISTRICT

East of the southern part of Lake Winnipeg is a band of rocks that differs from the prevailing granite and gneiss country north and south of it. In this band the rocks are largely Keewatin volcanic rocks partly converted into schists with which are sedimentary rocks bedded with the volcanics and others that are younger than the volcanics, all of which have been intruded by rocks of the granite and diorite classes, including porphyries. These are the classes of rocks that have proved so productive of gold in Ontario. The band extends eastward to the


INDEX MAP OF RICE LAKE DISTRICT
Scale of Miles
LEGEND
1 English Brook Area.
2 Wanipigow Lake Area
3 Saxton Lake Area.
4 Luleo Group.
5 Rice Lake Area.
6 Turtle Lake Area.
7 Elbow-Little Rice Lakes Area.
8 Gold Lake Area.
9 Eldorado Claims.
10 Kitchener Group.
11 Ore Grande-Solo Group.
12 Cryderman Claims.
13 Gorner-Gem Lakes Area.
14 Slate Lake Area.
Lake Winnipeg
MANITOBA
ONTARIO
Wanipigow L.
Turtle L.
Manigotagan L.
Rice L
Elbow L
Clearwater L
Gold L
Long L.
Halfway L.
Moore L.
Wallace L
Gem L.
Black R.

interprovincial boundary, a distance of about 55 miles, and continues for about 25 miles in Ontario. It follows in a general way the course of the Wanipigow or Hole River and the Manigotagan or Bad-Throat River, forming a belt from 5 to 20 miles wide. The course of these rivers, the general strike of the schists, and the long narrow shape of many of the rock masses, are features that have been caused by the folding of the rocks in folds having a general east-west direction. The consequent weakening of the rocks determined the shape of intrusions and the results of erosion.

Gold deposits have been found in all the rock formations of the district, but mostly in the schists of igneous origin. Discoveries have been made throughout the area from Lake Winnipeg to the Ontario boundary, but the largest amount of development work has been done on claims around Rice and Elbow lakes near the centre of the band and in the Bulldog (Beresford) Lake area at the eastern end where the zone of favorable rocks is widest.

In the 400 square miles included in the Rice Lake District, gold-bearing deposits have been found in a large number of places, and while the great majority of them are doubtless too small, lean, or irregular to be profitably workable, the same statement is true of most gold areas that have proved productive. The very general deposition of gold throughout this area warrants the development of the more promising prospects, and careful search for larger ore bodies that may be found near the discoveries showing rich samples but which are too small and irregular in values to make mines.

While the origin of the gold has not been definitely traced to any of the known intrusions of granitic rocks, the general similarity of the mineralization throughout the district points to one period of gold deposition. Quartz is always present where gold values are obtained, and it usually forms a large proportion of the deposit, not only as distinct bodies of quartz, but in the form of silicified country rock, that is, rock penetrated by the quartz material. It is a favorable feature of the ore deposits that this silicified rock contains pyrite and other ore minerals found in the quartz masses. Pyrite and copper pyrites are present in all the deposits. The best gold values seem to be associated with copper pyrites. Pyrrhotite, mispickel, galena, zinc blende, and molybdenite occasionally occur, but not prominently. Tellurides have been reported in some localities.

The gold deposits of the Rice Lake District are varied in form as is usual in Precambrian gold areas, the varieties including types all the way from small quartz veins in a tight fissure to wide shear zones traceable for thousands of feet. The latter type is likely to afford the best opportunities for developing gold mines. The best conditions seem to have been where the shear zones cross the strike of the schists and other rock structures at a small angle, rather than in those that follow the strike.

The Rice Lake District takes its name from the area north of Rice Lake, near the centre of the district. In referring to some of the individual deposits, the general order taken is from west to east, and, for con-

venience, deposits are grouped under the names of lakes and other topographical features.

Wanipigow River. Gold discoveries have been made along the north side of Wanipigow River in a belt a few miles wide extending from English Brook in the west to the country north of Rice Lake in the east. In the English Brook area the most interesting deposits lie between English Lake and the Wanipigow River. The **Lotus, Ling, Denver,** and **Dominion** properties show mineralized shear zones in porphyry and felsite striking about north and south. The Ling claim has a strong shear zone with a good deal of quartz and shows of free gold in many places. Both quartz and country rock in the shear zone are well mineralized with pyrite. Tetradymite, a telluride of bismuth, is reported. — Farther east are the **Betty, Bingo,** and **Wana** claims. A long, strong shear zone crosses the Betty and Bingo claims. Quartz is plentiful and in places both quartz and country rock are well mineralized with suphides, commonly pyrite. Mispickel is prominent in one place and tetrahedrite in another, both places being in the very wide shear zone on Betty 6. Underground work has been in progess on the Betty and Ling properties with the aid of a portable gasoline plant.

Wanipigow Lake. Gold has been found on many claims staked in the belt between English Brook and Wanipigow Lake and north of the latter. The most interesting deposits are those north of the east end of Wanipigow Lake. They are in township 25 and lie from 2 to 4 miles north of the lake. The rocks of the area are coarse-grained granite, granite porphyry and

granodiorite, with many inclusions of schist. These rocks are crossed in places by shear zones. That on the **Huronic claim** averages about 4½ feet in width about 2 feet of which is quartz for 200 feet along the strike. The minerals in the quartz are chalcopyrite, pyrite, and a telluride of gold. Free gold can be seen. The sulphides are said to assay as high as $120 a ton. The shear zones on the **Bingo** and **Bondholder** are narrow, but have been traced for several hundred feet in length. Free gold can be seen.

Saxton or Hay Lake. This lake is about 3 miles northeast of the east end of Wanipigow Lake. The rocks in the vicinity are mostly of the granite class, some of them porphyritic. Inclusions of schist are plentiful. The small amount of work done on claims in this area has revealed narrow shear zones with quartz in places, but the quartz is not abundant. It is occasionally mineralized with pyrite, copper pyrites, galena, and zinc blende, and good assays are reported from such places. The area is worthy of more systematic development.

Luleo Group. These and other claims are in an area 2 or 3 miles east of Saxon Lake. A large amount of underground work has been done on Luleo 2 claim. The rocks outcropping in the area are mainly granite with inclusions of schist. There are many shear zones with variable amounts of quartz and sulphides. On Luleo 2 a wide shear zone has a body of quartz 20 to 30 feet wide and over 300 feet long. The shear zone passes under low ground at both ends but has been picked up farther on. In the underground work the width of the quartz varied from very narrow to over

60 feet. The chief values in gold follow a zone within a few feet of the foot-wall, the bulk of the quartz showing only low values, but as values were obtained near the hanging wall at the surface, further development may show ore shoots. Pyrite is plentiful near the foot-wall, both in the quartz and in the schist. There are small quantities of copper pyrites, galena, and zinc blende in places, and mispickel is seen here and there. While quartz is the usual gangue, ankerite and other carbonates are plentiful in places. Sericite is often seen and in places the brilliant green color of chrome mica attracts attention. The later development work has been carried on by the **Selkirk Gold Mining Company**. It is possible that further development may show ore bodies that could be profitably mined, particularly with improved transportation for the district. The country east of the Luleo group is drift covered, but the few outcrops indicate that it is favorable territory. Several discoveries of gold have been made.

Turtle Lake Area. Turtle Lake is an expansion of the Manigotagan River, about 5 miles southwest of Rice Lake, and about a mile west of Elbow and Clearwater lakes. The country rock is mostly granite. The shear zones are from 2 to 10 feet wide. The quartz is not heavily mineralized. While free gold can be seen, especially in the neighborhood of copper pyrites, gold values in the quartz are not very encouraging.

Rice Lake Area. This area lies between Rice Lake and the Wanipigow River. It gives its name to the whole district, as the earliest gold discoveries of the district were made in the vicinity of Rice Lake. The lake is in a belt of schists that strike about southeast.

The principal gold discoveries have been made in the volcanic rocks, largely schistose, that form the north shore of the lake. The gold has been found in shear zones and bands of shattered rock, associated with quartz, carbonates, and other gangue minerals. Pyrite is present in both quartz and accompanying rock. Some underground work was done on the **Gabrielle** claim in the earlier years, a shaft having been sunk 52 feet and a short drift run in a deposit near the northwest shore of Rice Lake. A second deposit was developed to about the same extent. It lies in schistose porphyry, and consists of a sheared zone with a fairly regular vein of quartz, carrying values in an average width of about 6 feet. This deposit has been traced for several hundred feet. It is thought that the Gabrielle might be profitably worked, if there were better transportation provided.—East of the Gabrielle is the **San Antonio**, also somewhat developed in the earlier days. The property has been active again lately. A fracture zone in diabase has been followed across the whole claim. Irregular veins and lenses of quartz are prominent through the whole length of the zone. Free gold is plentiful in places. A shaft has been sunk 600 feet, and drifting and cross-cutting have developed considerable ore. Five veins have been found, one of which has a width of about 16 feet.

Many other gold discoveries have been made in the Rice Lake area, and it is possible that some of these or others brought to light by further prospecting may be developed into profitable mines.

Elbow Lake Area. Elbow Lake is about 3 miles south of Rice Lake. Little Rice Lake is a short distance

north of Elbow Lake. The most promising gold deposits in this area are east of these two lakes and within 2 miles of them. The rocks are schists with an east-west strike. Granite outcrops in the surrounding country. The gold is found in wide shear zones, most of which cut the schist at a small angle with the strike. The main shear zones have been traced across several claims. They carry bodies of quartz varying in size and shape. Both quartz and accompanying schist are in places well mineralized with sulphides. Free gold and small masses of rich ore have been exposed, but the large bodies of quartz that have been sampled do not carry encouraging values.

Gold Lake Area. Gold Lake is about 3 miles east of Elbow Lake. The area under consideration lies east of Gold Lake and stretches southwest to the shore of Clearwater Lake, a distance of about 4 miles, occupied mostly by schists, but with granite and granite porphyry outcrops. Gold has been found both in narrow quartz veins in tight rock, and in shear zones, the former sometimes showing much free gold. The veins and shear zones are usually in schist but a few occur in rocks of the granite class. A good deal of work has been done on the **Gold Pan, Gold Seal,** and **Gold Pan Extension,** about a mile south of Gold Lake. A shear zone from 1 to 8 feet wide has been traced for more than 3000 feet. Quartz lenses 2 or 3 feet wide have been followed for lengths of 50 to 100 feet. Mineralization with sulphides is irregular. Free gold is plentiful in places, and some exceptionally rich ore was taken out of a shaft on the Gold Pan sunk near a basic dike that crosses the vein. Shafts were sunk on these

claims to depths of over 200 feet and a good deal of drifting done, but the developments did not show workable bodies of gold ore. — The **Moose** claim is about a mile southeast of the Gold Pan. It is near the contact of schists with a body of granite. A shear zone in schisted porphyry crosses the claim. It continues into the granite, but the most promising part of the zone is in the schist. Veins and lenses of quartz occur here and there in this shear zone. Both quartz and schist are mineralized with sulphides, which are abundant and accompanied by free gold in places. Gold values are distributed irregularly. A shaft was sunk 100 feet and drifts run at that depth. The quartz showed widths of 2 to 6 feet. This shear zone merits more exhaustive development. —Another strong shear zone has been traced across a group of claims lying about midway between the Gold Pan and Clearwater Lake. The claims crossed are the **Pilot, Jumbo, Smuggler,** and **Lucky Strike**. The shear zone has been well exposed by stripping, trenching, test-pits, and shallow shafts It is so large and well marked, and so well mineralized that it invites careful sampling in a search for ore shoots. There are other shear zones in this area showing abundant quartz and sulphides. — The **Pendennis** claim, on the north shore of Clearwater Lake, has a rich quartz vein from a few inches to 3 feet in width. It has been stripped and trenched for over 200 feet. Free gold is abundant in places. A shallow shaft has been sunk and a few tons of rich ore taken out.

Long and Beresford Lakes Area. This gold area lies between the headwaters of the Wanipigow and Manigotagan rivers taking in the country between Wallace

Lake in the north and Slate Lake near the Ontario boundary in the South. The discoveries are associated with Long, Halfway, Moore, Beresford or Bulldog, Garner, Gem, and Slate lakes. The most important are here described beginning on the western side of the area where the rocks are granite, granodiorite, and related species. The **Eldorado** claims are south of Halfway Lake. They show two larger and several less important shears in granodiorite. The most important zone has been traced for 1800 feet. It is from 3 to 10 feet wide, and quartz occupies about one fourth of the width. A parallel zone with quartz has been traced 1000 feet. Free gold is apparent in most of the quartz and the gold values are fairly uniform. Both quartz and associated schist are mineralized with pyrite and a less amount of copper pyrites. Channel samples show a deposit workable if transportation is improved. Two shafts have been sunk, one of which is over 500 feet deep. Drifting is going on. The mine is connected with the electric power line that has been run to Central Manitoba Mines a few miles east. North of Long Lake, a feeder of the Manigotagan River, a number of discoveries have been made. The **Elora Fractional** has been developed by an open pit 100 feet long, and several thousand dollars worth of gold bullion produced in 1922 from very rich ore. A two-stamp mill was used. The gold was in irregularly distributed rich pockets associated with a good deal of mispickel. — A number of other small but very rich veins have attracted a good deal of attention, and in 1923 a five stamp-mill was built on the **Onondaga** claim where a shaft was sunk 100 feet on a rich vein 3 feet wide.—

Beautiful specimens of crystallized gold have been found in the quartz on the **Mirage** claim, one mile east of Bijou Lake. — The **Maberly** claims are a little east of Stormy Lake. A strong, wide shear zone cuts andesite schist at a small angle. The numerous outcrops show quartz in veins, lenses, and stringers, well mineralized with pyrite. The average width of the quartz is important and gold values are said to be encouraging.

The **Kitchener** group of claims is about 3 miles northwest of Beresford (Bulldog) Lake. A strong shear zone has been traced for about 2 miles. This property has been developed into a producing gold mine by **Central Manitoba Mines Limited.** The ore is mostly quartz mineralized with pyrite and copper pyrites, and gold is not visible except after fine grinding and panning. With the quartz is a certain amount of mineralized schist that carries gold. The Kitchener shear zone lies in andesite and other more acid schists. The best ore is that containing copper pyrites. Surface sampling showed a mining width of $13 ore for a length of over 900 feet. Underground work showed a greater length of ore, at least 1500 feet, but of a little lower value. The **Tene 6** claim, about three quarters of a mile east of the Kitchener is owned by Central Manitoba Mines. It shows an ore body traced for 190 feet with values of $15 to $25 over a width of 16 feet. A shaft sunk 250 feet is in ore all the way. A 150 ton mill was built in 1927, and its capacity has since been increased. In May, 1928, the ore reserves were estimated at 141,334 tons valued at $1,206,740, and development work has greatly increased the amount

since that date. The mine is now (1929) producing gold to the value of about $40,000 a month. Power is obtained from Great Falls on the Winnipeg River through the Manitoba Power Company. The nearest rail connection is the end of steel at Great Falls, 55 miles away.

The **Oro Grande-Solo** group is at the north end of Beresford (Bulldog) Lake a few miles east of Central Manitoba Mines. The property has been operated by the Anglo-Canadian Company, but changed bands in 1928. The old shaft has been deepened to 500 feet, and cross-cutting and drifting have been carried on. The surface and underground work have determined a length of 1100 feet for a quartz vein that outcrops a few hundred feet west of the north end of the lake. The vein is probably of workable width for most of this length. The width varies from a few inches to 6 feet. The ore is said to average $13 a ton, and, while the vein is narrow, the property seems to have possibilities as a small producer of gold.

The **Cryderman** claims are about 4 miles northwest of Moore Lake (also called Partridge Lake), and about the same distance south of the west end of Wallace Lake. There is a wide shear zone that has been traced for 1500 feet by bodies of quartz varying from a few inches to 25 or 30 feet in width. The shear zone is probably at least 3600 feet long. A smaller vein was first discovered, northeast of this shear zone, to which it is nearly parallel for part of its length. The veins are in volcanic schists, and the quartz is mineralized with pyrite, copper pyrites asd a little pyrrhotite. Free gold can be seen in the outcrops of both veins,

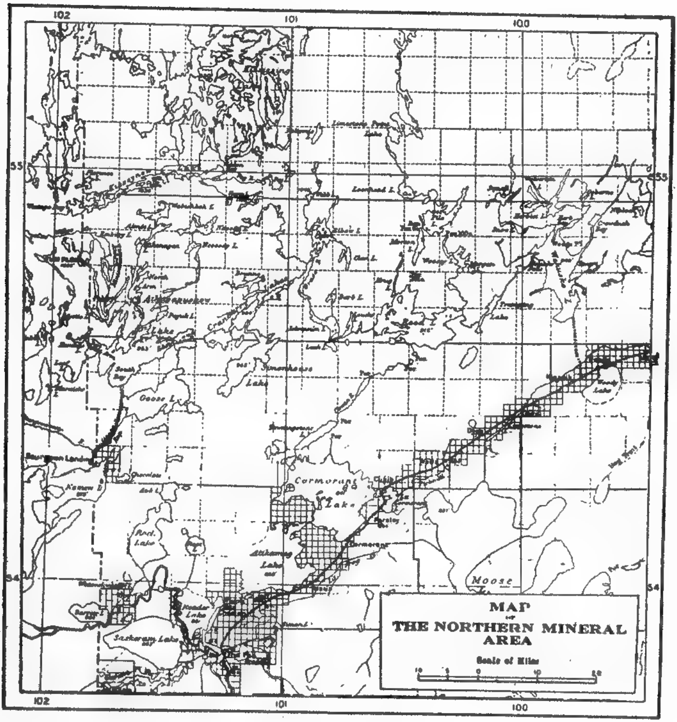
and tellurides have been identified. Preliminary underground work gave rather disappointing results, but, after a period of idleness, the property is active again.

A number of discoveries have been made near **Garner** and **Gem** lakes, a few miles southeast of Beresford Lake. **Gem Lake Mines** is a property that has been considerably developed. Three veins have been located on the surface, and by shaft and crosscuts, these veins have been intercepted underground. They show free gold. No. 3 vein shows payable values on the surface. It is being tested underground. The shaft is down 375 feet, and 2000 feet of drifting and cross-cutting has been done. This property is near the Ontario boundary. —Farther south, between **Slate Lake** and the Ontario boundary, several interesting discoveries of gold have been made, but their development has not been carried far enough to indicate their importance.

The successful operation of Central Manitoba Mines, and the supply of electrical power now available, insures a fair trial of all properties of merit in the Rice Lake district. If a railway line is run through this and the Red Lake district in Ontario, properties may be brought to profitable production that could not be made to pay in face of the present expensive transportation.

Northern Manitoba

The territory included under this name is north of Township 44 and extends to the sixtieth parallel of latitude, the north boundary of the Province, making an area of 178,000 square miles, about five sevenths of

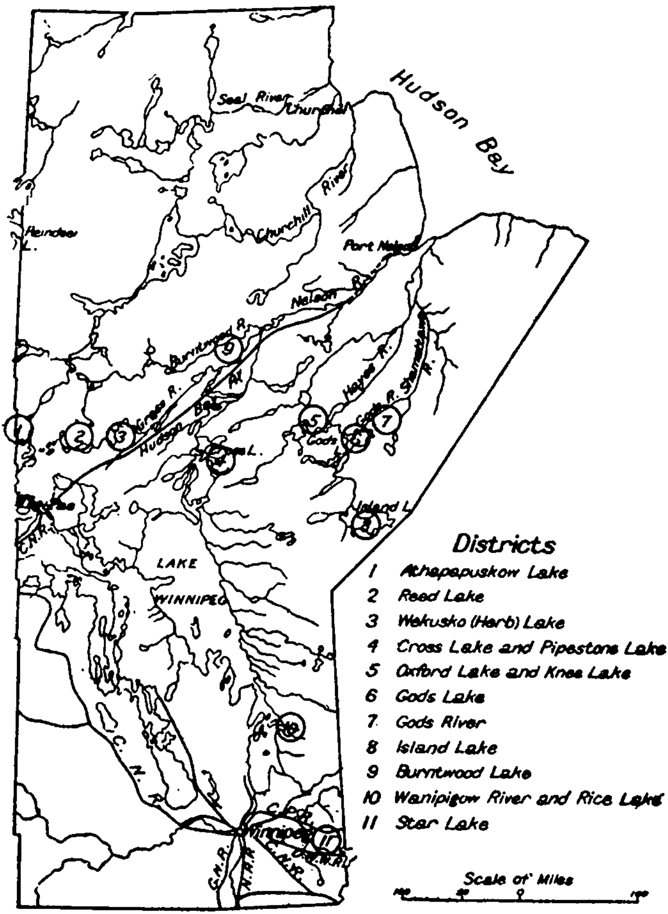


MAP
OF
THE NORTHERN MINERAL AREA

the total area of the Province. This territory was added to Manitoba in 1912. It includes the northern part of Lake Winnipeg with the Paleozoic beds west and northwest of that lake. Gold discoveries have been made principally in a strip of country lying just north of the northern limit of the Ordovician formations and stretching from the Saskatchewan boundary at Flin Flon lake eastward beyond Wekusko or Herb Lake. It thus comes within easy distance from the Hudson Bay railway. This belt is from 10 to 25 miles wide and about 110 miles long. It is underlain by Keewatin lavas much altered and conveniently classed as greenstone or greenstone schist, with schists of sedimentary origin and also less altered sedimentary beds. These formations are intruded by granite, porphyries, and other igneous rocks. The belt is flanked on the north by large areas of granite and gneiss that penetrate and break it up into irregular bands with a northeast-southwest strike. Other similar areas are found east of the Hudson Bay railway around Cross, Pipestone, Oxford, Knee, God's, and Island lakes, and a long strip of these favorable rocks occurs along the Burntwood River. The country to the north has not been geologically mapped in detail, but recent explorations have shown that there are a number of areas of greenstone, etc., in the large spaces formerly mapped as granite and gneiss or set down as unexplored.

The gold discoveries in the main belt are conveniently referred to in groups named from lakes around which they occur. From west to east the areas are (1) Flin Flon and Schist Lake, (2) Athapapuskow Lake,

(3) Copper and Brunne Lakes, (4) Wekusko or Herb Lake.



FLIN FLON AND SCHIST LAKE AREA

This area is next to the Saskatchewan boundary beyond which it extends westward about 20 miles in Saskatchewan. The great **Flin Flon** ore body is mostly on the Manitoba side of the line. It is primarily a zinc-copper deposit but carries small values in gold (See **Copper** p. 81 and **Zinc** p. 107) — The **Mandy** copper mine on Schist Lake is about 4 miles southeast of the Flin Flon. The high-grade copper ore taken from the Mandy carried $200 a ton in gold value. (See **Copper** p. 83).

ATHAPAPUSKOW LAKE AREA

Prospecting has been most active around the north arm, the Pineroot River, and around the east arm. Most of the work has been done on copper claims, but a number of gold-quartz veins have been discovered. Manitoba Basin reports a discovery on the north arm about three miles from the Flin Flon railway.

On the **Don** claim, a narrow quartz vein mineralized with pyrite and copper pyrites has shown some very rich spots of gold and tellurides.— Prospecting around Twin Lake, north of the east arm of Athapapuskow Lake, has shown several narrow quartz veins in bands of felsite that carry a little pyrite. Some of the veins show galena and zinc blende.

COPPER AND BRUNNE LAKE AREA

Under this name may be included the country around Copper, Brunne, and Cranberry lakes, making an area about 18 miles square, mostly granite. Copper lake is surrounded by greenstone, etc., and these favorable rocks form the north shore of Brunne Lake. They also

follow the northeast-southwest course of Second and Third Cranberry lakes and Grass River to Elbow Lake (not to be mistaken for Elbow Lake in the Rice Lake District) around which the greenstone formations attain a breadth of about 6 miles east and west.

The **Big Dyke** is on the west side of Copper Lake near the north end of the lake. A quartz vein 15 to 30 feet wide has been traced for more than 2000 feet across the **Contact** and **Contact Extension** claims. The quartz is mineralized with galena. Good values in gold are reported from channel samples. The vein is near a granite contact.

The **Red Rose** claim is immediately east of the **Big Dyke.** A narrow quartz vein has a very rich gold shoot. The vein is from six to eighteen inches wide, and it has provided remarkably rich specimens.

The **Bluebird** claim is over a mile northeast of the Big Dyke and probably on the same general strike with it. An 18-foot quartz vein has been exposed by trenches. The quartz is mineralized with galena, pyrite, and a little copper pyrites.

Between Copper Lake and Brunne Lake a good deal of work has been done on wide bands of pyrite and pyrrhotite in greenstone schist and felsite.

The **Silverbell** claim is northeast of Copper Lake. Abundant free gold was found in a mass of quartz 11 feet wide, but the shoot was found to be only 4 feet deep.

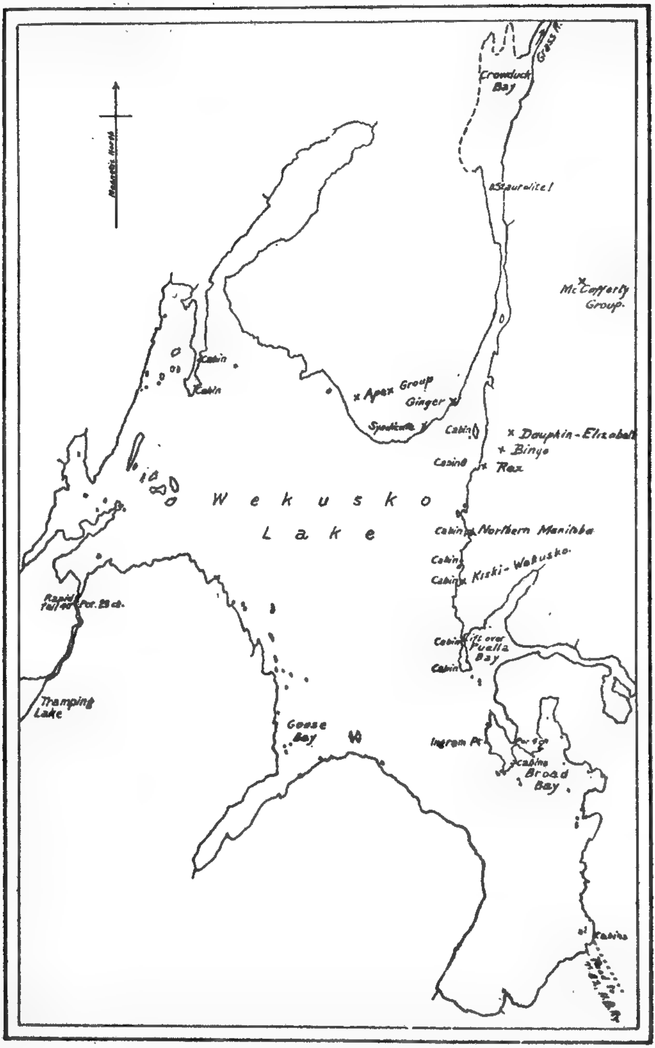
On the **Caribou** claims on the west side of Brunne Lake there is a band of almost solid pyrite and pyrrhotite the width of which is about 75 feet. Values in gold, copper, platinum, and nickel have been reported.

On **Webb Creek**, north of **Elbow Lake**, there are zones of sulphides at the contact between granite and greenstone. Grab samples have shown only low values in gold.

HERB OR WEKUSKO LAKE AREA

The first discovery in this area was made in 1914 by R. Woosey and M. Hackett. The south end of the lake is 10 miles north of mile 82 on the Hudson Bay railway. The contact between the Precambrian and the Paleozoic lies just south of the lake, Ordovician dolomite forming part of the south shore. The Precambrian rocks around the lake include basic and acid lavas largely changed to schists; other schists of sedimentary origin including garnet-gneiss and hornblende schist; conglomerate and graywacké; and intrusive granite and pegmatite. These formations are largely in long narrow bands with a northeast-southwest strike, the general direction also of many of the long bays and lakes characteristic of the northern part of the area. Gold has been found mostly in narrow quartz veins mineralized with mispickel, pyrite, and copper pyrites. Mispickel is the characteristic mineral. It is usually concentrated at the margins of the veins and in the walls. The frequent occurrence of tourmaline is evidence of the high temperatures at which the deposits were formed.

The **Rex** mine is at the northeast side of the lake near the mouth of Crowduck Bay. The vein is at the contact between conglomerate and other sedimentary rocks with acid lava. The strike conforms with the general strike of the country. The vein is from 3½ to 5 feet wide. It has been traced 1700 feet in length.



Wekusko (Herb) Lake, Showing Mineral Properties

Scale of Miles

The values are uniformly high, $19 a ton being the value extracted throughout a 50-foot drift. In 1918 from May to the end of November, bullion of the value of $27,000 was recovered by means of a small stamp mill.

The **Northern Manitoba** property is near the lake shore about 2½ miles south of the Rex Mine. A quartz vein six inches to thirty inches wide has been followed on the surface for about 300 feet, and has been develloped by underground work. The gold values are high. A carload of ore averaged $81.53 a ton.

The **Kiski-Wekusko,** the original discovery, is near the lake shore about 2 miles south of the Northern Manitoba. Three veins have been stripped, and a shaft sunk on one of them that has a maximum width of 6 feet. The quartz is mineralized principally with mispickel, but copper pyrites and galena occur. Tourmaline is abundant. One vein has been traced for more than 700 feet.

The **Bingo** mine is a short distance northeast of the Rex. There are four narrow quartz veins in a width of six feet. The quartz shows plentiful free gold.

The **Dauphin-Elizabeth** claims are about half a mile north of the Bingo. A quartz vein from 3 to 6 feet wide has been traced for about 1000 feet. The vein is a strong one, but the mineralization with mispickel, copper pyrites, and galena is only sparing. The property is owned by **The Pas Consolidated Mines.**

The **McCafferty** claims are about 3½ miles north of the Dauphin-Elizabeth, east of the narrows leading into Crowduck Bay. A quartz vein has been stripped

for 300 feet and is said to have been followed for a total distance of 1600 feet.

The **Apex** group is near the end of a peninsula that juts out into Herb Lake between Herb Bay and Crowduck Bay. This peninsula is underlain by granite with a fringe of greenstone around the shores. The Apex claims are in the granite near the west shore and not far from the contact. The mineralized zone averages 15 to 20 feet wide, and is 60 feet wide in places. There is no distinct vein. The granite has been sheared and altered by the deposition of quartz with mispickel, pyrite and a little copper pyrites. It is reported that channel samples across widths of 15 to 20 feet show values from $1.50 to $24.00 in gold. The mineralized zone has been traced for about 1000 feet.

The **Syndicate** claims are near the east shore of the peninsula between Crowduck narrows and Herb Bay. The vein lies in the greenstone near the contact with granite. It is narrow but has been followed for 700 feet in length. The quartz shows only a little mineralization with sulphides, but free gold is frequently seen, and carbonate of iron is fairly plentiful.

The **Ginger** claim, about a mile northeast of the Syndicate, has a quartz vein with considerable molybdenite.

The **Twin Lakes Group** is on the peninsula between Little Herb Bay and Grass River. Gold occurs in pegmatite granite that grades into quartz veins. The values are found in wide zones that are mineralized with mispickel, and a little pyrite and copper pyrites. The mineralized zone is 40 feet wide in one place.

The **Cabin** claim is on the long north arm of Little

Herb Lake. This lake is a few miles northwest of Herb Lake. The shores of the arm are fringed with greenstone separating it from the granite that underlies most of the country. On the Cabin claim some work has been done on a narrow quartz vein mineralized with pyrite, copper pyrites and bornite. The sulphides are also found in the hornblende schist of the wall rock, and gold values have been found in this schist. The vein has been traced on the surface for a length of 250 feet.

The **Manitoba Basin Mining Company's** property is at the south end of Herb Lake. It is being prospected by diamond drilling.

PIPESTONE LAKE AND CROSS LAKE

These lakes are east of the Hudson Bay railway and are practically continuous through numerous narrows separated by islands. The basin of Pipestone Lake is in a band of greenstone that forms most of the shore line and extends inland to contact with granite. With the greenstone has been folded a band of conglomerate, arkose, and sedimentary gneiss. These rocks form many of the islands and are also seen at places along the shores of the mainland. Intrusive granite shows on some of the islands. The general strike of the rock bands and contacts is northwest-southeast. That of Cross Lake is northeast-southwest. This lake is pretty completely surrounded by granite, but most of the islands in the northeast half are formed of greenstone. In the southwest half, islands and points are underlain by the sedimentaries. The area of greenstone

and associated sedimentary rocks extends a long distance east of Pipestone Lake.

OXFORD LAKE AREA

Oxford, Knee, and God's lakes are east of the Hudson Bay railway in about the same latitude as Cross and Pipestone lakes. Island Lake is due south of God's Lake. All these lakes are in the part of Manitoba between the Hudson Bay railway and the Ontario boundary. Oxford Lake is surrounded by a rather large area of greenstone, etc. that extends northeastward down the Hayes River. It is about 80 miles long with an average width of about 20 miles. A parallel band of favorable country lies about 20 miles to the southeast, with God's Lake in its northern and Beaverhill Lake in its southern part. While the geology of all these areas is favorable, the difficulties of transportation preclude the exploitation of any but the richest mineral deposits. Prospecting has gone on for several years and interesting discoveries have been made.

ISLAND LAKE

Island Lake is about 145 miles southeast of mile 219 on the Hudson Bay railway and about 170 miles north of the Red Lake area in Ontario. The main body of the lake is 45 miles long and from 9 to 13 miles wide. The islands are very numerous and so spaced as to leave no large bodies of open water. The rocks are Precambrian and divisible into groups similar to those characteristic of mineral-bearing areas in Manitoba, Ontario, and Quebec, namely, (1) the oldest group consisting of Keewatin volcanics largely con-

verted into schists, and old sedimentary rocks, partly interbedded with the volcanic schists and partly forming a series including slate, graywacke, quartzite, and conglomerate; (2) a younger series of sediments including quartzite and conglomerate; (3) older basic intrusives (diorite and gabbro); (4) intrusions of granite, granite porphyry, pegmatite, aplite, etc., and (5) intrusions of diabase, the youngest rocks in the area. The granite intrusions are numerous and some of them are very large. It is possible that within the bounds of these there may be areas of the older rocks favorable for the occurrence of mineral deposits. There are also many small masses of granite such as are characteristic of the best prospecting ground in other regions. The area is being prospected, and interesting discoveries of gold have been made.

Production: In 1928, the gold production of Manitoba was valued at $409,571. In 1929 production was at the rate of about $50,000 a month.

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SILVER

The greater part of the world's silver production comes from ores of lead, zinc, and copper, and particularly from lead-zinc ores. In the reduction process, the precious metals go with the base metals and are recovered in various ways in refining.

The principal silver minerals are described at page 5. In the ores of lead and zinc, the silver is mostly part of galena and zinc blende, but in very rich ores, it may appear as argentite, the sulphide of silver, and occasionally native silver is seen in lead and zinc ores.

Native silver in commercial deposits has not been discovered in Manitoba. The rich copper ore taken out of the Mandy Mine carried 2.5 ounces of silver per ton, and the comparatively lean ore left in the mine carries substantial values in silver. In the Flin Flon ore body the average silver content is a little over one ounce a ton.

On Little Herb River there is a depôsit of galena and zinc blende in quartzite. The ore carries silver to the extent of about one ounce per ton for every unit per cent of lead.

Silver values have been found in some of the large bodies of pyrrhotite and other sulphides.

The copper-zinc ore of the Sherritt-Gordon mine at Kississing (Cold) Lake carries small values in silver. The silver in the ore of the Flin Flon, Sherritt-Gordon, and other large bodies of sulphides will be recovered as a by-product in the electrolytic refining of the copper and zinc. While the proportion of silver is small, the total annual production from these extensive ore bodies will be large. (See pages 82, 83, 84 and 88).

Galena carrying silver values has been reported from a number of places in Northern Manitoba. Five feet of lead ore has been exposed over a considerable length at the Ruby property of Cold Lake Mines, Ltd. Silver values are reported from Puella Bay, Herb Lake, in a long vein of lead-zinc ore.

In Southeastern Manitoba, some of the copper-nickel ore deposits in the Oiseau or Bird River area carry silver. For example, the ore on the Wento claims carries from 2 to 4 ounces of silver per ton, and the Cup Anderson ore, from 1.3 to 3 ounces.

Silver-bearing calcite veins are reported to occur in the Oiseau River area near the Regal group of claims, Calcite veins with a little galena and low values in silver occur on the Zeemel claims just east of the east end of Lac du Bonnet.

THE PLATINUM METALS

The metals of the platinum family are **platinum, iridium, osmium, palladium, rhodium,** and **ruthenium.** They are found in natural alloys containing several and sometimes all of these metals. Native platinum sometimes contains iron, up to 18%. **This makes it**

more or less magnetic according to the proportion of iron. In washing gravel for placer gold, platinum, being a very heavy metal, goes with the gold and other heavy minerals. Among these is the magnetic mineral magnetite, which is often separated from the gold by means of a magnet. Platinum that has a considerable percentage of iron in it will be separated with the magnetite.

Platinum is found in dunite, peridotite, and other basic rocks. In the Ural Mountains, Russia, large masses of platinum have been found in dunite, a rock composed mostly of the mineral olivine; but the greater part of the platinum of commerce has come from placer diggings. The discovery in South Africa of extensive ranges of platinum-bearing rocks may make a change in this respect. There, platinum has been found in a great variety of rocks, including quartz veins.

Small quantities of the platinum metals have been found in the sulphide deposits of the Oiseau River and the Maskwa River areas, but platinum in commercial quantities has not so far been discovered in Manitoba.

CHAPTER IV

METALLIC MINERALS (Cont'd)

COPPER, NICKEL, COBALT, IRON

COPPER

Ores. The principal ores of copper are **native copper; copper pyrites** or **chalcopyrite,** composed of **copper,** 34.5%, iron, and sulphur; **bornite,** copper, 50 to 70%, iron, and sulphur; and **chalcocite,** copper 79.8% and sulphur. A number of other copper minerals are sometimes found in sufficient quantities to be of use as ores. **Tetrahedrite** or **gray copper ore** is composed of copper, 52.1%, antimony, and sulphur. It may carry silver or mercury in important amounts. **Malachite** and **azurite,** the carbonates of copper, form the green and blue stains and crusts that are sometimes a guide to the underlying sulphides or other ores of copper. The carbonates are formed by the weathering of the sulphides, etc., and while they may occur in important amounts in countries where weathering has extended to considerable depths and the products have not been removed by erosion, the glaciation of Manitoba has carried away at least the majority of such deposits. **Cuprite,** or **red copper ore,** is an oxide of copper containing 88.8% of the metal. **Tenorite** or **mela-**

conite is another oxide, black in color. **Covellite** or **indigo copper** is a rather rare sulphide of copper. Other minerals containing copper are **bournonite,** composed of lead, copper, antimony, and sulphur, **tennantite,** and **enargite,** composed of copper, arsenic, and sulphur.

In describing the distribution of copper minerals in Manitoba only those occurrences are mentioned which are either of some economic importance or may indicate the advisability of further exploration in their neighborhood.

Southeastern Manitoba

BOUNDARY DISTRICT

The Boundary District is the part of Southeastern Manitoba adjoining the Lake of the Woods region in Ontario. While no commercial copper ore bodies have been discovered in the district, the occurrence of extensive sulphide zones in schist north of Falcon Lake and near West Hawk Lake makes it possible that similar zones may be found with a payable percentage of copper.

OISEAU RIVER AREA

The Oiseau or Bird River area begins 70 miles northeast of Winnipeg and extends eastward to the Ontario boundary, a distance of 30 miles.

The area is traversed from east to west by the Oiseau River which empties into the Winnipeg River through Lac du Bonnet. The Winnipeg River crosses the southeastern part of the area. The terminus of the City of Winnipeg railway is at Point du Bois on an expansion of Winnipeg River near the southern boundary of the area.

The rocks underlying the Oiseau area are more or less altered sedimentaries interbedded with volcanic rocks, the whole being intruded by a series of rocks ranging in composition from granite to peridotite. The contacts between these intrusions and the intruded rocks are in a general east-west direction, which is also the direction of the two rivers for considerable parts of their course. Numbers of long lakes show the same lines of weakness. A second direction of weakness in the rocks is indicated by intrusive bodies with a north-south strike, and by lakes and reaches of the rivers with their length in that direction.

The known deposits of sulphides are in a zone of andesite lava and volcanic tuff between the west end of Oiseau Lake and the north end of Lac du Bonnet. In this zone are dikes and bosses of the more highly basic rocks including gabbro and peridotite, and the majority of the known deposits are at least fairly closely associated with these intrusives. Others are in the andesite and tuff far from any known intrusion of gabbro or peridotite. Prospecting should therefore be carried on over the whole extent of country enclosed by the large granite and gneiss areas that occupy the northern and southern parts of the area. The lines of contact between the basic rocks and the granite should also be examined.

The minerals have been deposited in fracture and shear zones in the andesite and tuff or in schisted rocks at the contacts of these two kinds of rocks with one another or with peridotite, gabbro or granite. The ore minerals include copper pyrites with some rarer copper iron minerals, pyrrhotite, pentlandite (See

Nickel p. 92), pyrite, magnetite, mispickel, galena, and zinc blende. The presence of magnetite in the ore deposit and of epidote, hornblende, etc., in the gangue, indicates the high temperatures at which the minerals were deposited. The deposits that may be of importance for their copper content are of two classes (1) those composed largely of chalmersite (magnetic copper pyrites), copper pyrites, pyrrhotite, and pyrite; and (2) those in which copper pyrites is the principal ore mineral along with galena and zinc blende. The deposits of class (1) occur at or near the gabbro-andesite contacts. The ore appears as lenses of schisted rock with chalmersite and chalcopyrite, or of gabbro impregnated with these sulphides and rich in hornblende. Class (2) includes replacement deposits in andesite and tuff near the granite contact. The characteristic minerals are copper pyrites, galena, and zinc blende. These deposits are thought to be the most important in the area.

The **Wento** claim is north of the Oiseau River in Tp. 17. R. 15, near contacts between andesite and tuff with gabbro and granite. The ore deposit consists of schisted andesite and tuff with lenses, stringers, and bunches of pyrrhotite, chalmersite, copper pyrites, and pyrite. The presence of magnetite and hornblende indicates high temperature conditions of deposition. The mineralization seems to be very extensive, being exposed for 300 feet east and west with a north-south width of from 5 to 100 feet. Assays over a width of 17 feet at a depth of 25 feet averaged 5.2. per cent of copper and 2.5 ounces of silver to the ton. Large masses of solid sulphides have assayed 14 per cent of cop-

per. It is thought that an important tonnage of ore is available that would assay 3 per cent of copper and 2 to 3 ounces of silver to the ton. The depth to which weathering has extended is unusual in a glaciated country, being at least 25 feet. The copper content may be larger at lower levels. The property is owned by the Manitoba Copper Company, Ltd.

The **Cup Anderson** claims are about half a mile northeast of the Wento. The ore body is a replacement deposit in tuff and andesite much schisted and characterised by the abundance of garnets. The mineralized zone as exposed by trenches is up to 100 feet wide, but the average width of commercial ore throughout the 400 feet prospected is probably between 25 and 40 feet. Channel samples across 28.5 feet averaged 3.8 per cent of copper and 1.3 ounce of silver per ton. In another place, channel samples across 94 feet gave 4.1 per cent of copper and 1.4 ounce of silver per ton. Several hundred thousand tons of this ore is indicated. On each side of the main ore body there is a large tonnage of mineralized schist that averages less than 1.5 per cent of copper. The claims are controlled by the Manitoba Copper Company, Ltd.

The **Devlin** claims are about a mile east of the Cup Anderson. There is a large zone of sulphides in andesite schist near a granite contact that strikes nearly east and west. It has been traced for 800 feet on the Devlin and the adjoining Martin property. Its width varies from 2 or 3 feet up to 70 or 80 feet. The ore minerals are pyrrhotite in large quantities with copper pyrites in smaller amounts. Channel samples gave about 1 per cent of copper and ½ per cent of nickel in

the better-looking parts of the zone, but a commercial grade of ore can be obtained in comparatively narrow widths.

The **Chance** claims are about half a mile east of the Devlin. The deposit is in basic schist near an east-west granite contact. The sulphides are mainly pyrrhotite, pentlandite, and chalmersite. The ore averages about 2 per cent of nickel and less than ¼ per cent of copper. (See **Nickel** p. 92).

These examples indicate mineralization on a large scale. Careful prospecting may reveal ore bodies of higher copper content. There is a good deal of low wet ground in the region, and the better copper ore deposits may be concealed by this. Deep weathering followed by glaciation would tend to cause hollows above the places where the sulphides are concentrated.

MASKWA RIVER AREA

The Maskwa River area is around the headwaters of a branch of the Winnipeg River that empties into that river about ten miles from its mouth. The area is northwest of the Oiseau River area. These two rivers are often named Bear River and Bird River, the English equivalents of **Maskwa** and **Oiseau**, but the French and Indian words are more distinctive. The Maskwa River deposits are much like those north of the Oiseau. They occur near contacts of gabbro and basic schists, and the sulphides are more plentiful in the schists. Pyrrhotite is most abundant, and copper pyrites less so in general, although prominent in places. Samples have assayed from ½ to 3½ per cent of copper and smaller quantities of nickel (See **Nickel** p. 92). A

considerable body of low-grade ore was proved by diamond drilling on the Mayville and Hititrite claims. The work was done for the Devlin Mining and Development Company.

Northern Manitoba

Sulphide deposits carrying copper occur in a greenstone belt about 100 miles long and up to 15 miles wide extending from the Saskatchewan boundary at Flin Flon Lake eastward beyond Wekusko or Herb Lake. This stretch of country is sometimes called The Pas Mineral Belt. It is just north of the Paleozoic limestone which doubtless covers similar rock formations farther south. There are other areas of greenstone east of the Hudson Bay railway and north of the belt under consideration (See **Gold** p. 61). While there are indications of copper ore at many points in this belt and in other areas, the discovery of large bodies of commercial copper ore at Flin Flon and Schist lakes has concentrated activity in the western part of the district. The district has been opened up by a branch of the Hudson Bay line of the Canadian National railway about 87 miles long. This has been extended about 45 miles northward to Kississing (Cold) Lake to serve another very important copper ore deposit, that of the Sherritt-Gordon Mine.

FLIN-FLON — SCHIST LAKE AREA

Flin Flon Lake lies partly in Manitoba and partly in Saskatchewan; Schist Lake is a few miles southeast of Flin Flon and wholly in Manitoba.

Flin Flon Mine. This property is on the east shore of Flin Flon Lake. The ore deposit extends under the

lake. It has been developed by the **Hudson Bay Mining and Smelting Company.** By diamond drilling the length of the ore body has been determined as 2593 feet. The average width is about 70 feet, but the central part of this immense deposit is 300 feet wide. It has been proved to a depth of 900 feet over a length of 1000 feet. The ore is in a shear zone having a northwest strike. The rock is greenstone, in places amygdaloidal. The greenstone is intruded by quartz porphyry on the hanging wall side. On the footwall side is an intrusive basic dike. The greenstone is schisted in part and the sulphides have been deposited in the schisted parts by replacement. This process has not taken place in the more solid parts of the rock. The total ore body, both solid and disseminated sulphides, as proved by diamond drilling to a depth of 900 feet, amounts to 16,812,290 tons, with possible further tonnage of 2,975,100 tons. The average content of this ore is 1.71 per cent of copper, and 3.45 of zinc. The gold value averages 0.074 ounce and the silver, 1.04 ounce per ton. The ore minerals are pyrite, zinc blende, copper pyrites. and magnetite. (See **Zinc** p. 107 and **Gold** p. 63). There is a zone of solid sulphides in the centre of the deposit, the ore being disseminated towards the walls. The widest part of the ore body will be mined by open pit methods, by which it is estimated that about five or six million tons of ore can be taken out by electric shovels. This very cheap mining method cannot be applied to the main bulk of the ore, which will be mined through a shaft capable of hoisting 3000 tons a day. The ore is concentrated by oil flotation, by which it is possible to separate the copper sulphide

from the zinc sulphide. The tailings, mostly pyrite, are cyanided to recover the part of the gold and silver not carried along with the copper and zinc concentrates. The concentrator has a capacity of 3000 tons a day. The annual production is estimated as 30,000,000 pounds of copper and 50,000,000 pounds of zinc. The production of gold is roughly estimated as about $1,600,000 a year and that of silver $500,000.

The copper concentrates are smelted with the final production of "blister" copper ready for electrolytic refining. The zinc concentrates are treated by an electrolytic method. These operations imply an abundant supply of cheap electrical power. This comes from Island Falls on the Churchill River, 75 miles to the northwest.

Several other copper-zinc deposits are being developed in the Flin Flon area, including the **Callinan Flin Flon** and the **Flintoba properties.**

Baker-Patton. This property is about 11 miles northeast of the Flin Flon. A shaft has been sunk 425 feet. Diamond drilling is reported to have intersected 40 feet of 3% copper ore.

Mandy Mine. This property is on the northwest arm of Schist Lake about 3 miles southeast of the Flin Flon deposit. The ore body is in a schisted and faulted zone in greenstone. The deposit resembles the Flin Flon in a general way, there being a zone of solid sulphides in the middle with disseminated ore towards the walls; but the Mandy had a large lens of high-grade copper pyrites near the foot wall. This ore averaged 19 per cent copper, and 10 ounces of gold and 2½ ounces of

silver per ton. It has been stoped down to 225 feet where this lens pinched out. The total amount of this rich ore taken out was 25,000 tons. There remains blocked out in the mine about 200,000 tons of low-grade copper-zinc ore. Since the building of the railway, the ore deposit has been extensively explored with a view to resumption of mining operations.

Maybee Claims. This property is south of the Mandy and on the same strike. The mineralization of a greenstone zone extends over a width of 20 feet. The minerals are copper pyrites and pyrite in stringers.

Hook Lake is west of the Inlet arm of Schist Lake. Stringers of copper pyrites and pyrite occur near a granite contact. Chalcocite was found in considerable quantities in a test pit.

LeVasseur Claims. These are on the northeast arm of Schist Lake. A narrow shear zone shows pyrite and copper pyrites, the latter in larger proportion at the bottom of a 6-foot test pit.

On the west side of the northeast arm there are a number of showings of copper pyrites, and in one place the rusty surface shows mineralization for a width of at least 100 feet. Where the zone is quartzose, scales of native copper can be seen.

ATHAPAPUSKOW LAKE AREA

Athapapuskow Lake lies a few miles south of Schist Lake. A western arm crosses the Saskatchewan boundary. Copper pyrites and bornite occur in many schisted bands of greenstone around the north and east arms of the lake and along Pineroot River north of the lake.

Chica Claims. This property is near the mouth of Pineroot River. A narrow zone of sheared porphyry lies between intrusive granite and conglomerate. It shows pyrite and scattered copper pyrites. It is stated that a lens of copper pyrites was cut at the conglomerate-porphyry contact in a diamond drill hole.

East Arm. There are a number of showings of copper pyrites and bornite along the north shore of the east arm of Athapapuskow Lake. The minerals occur in bands of greenstone schist that show stringers of epidote. Three such parallel bands striking northeast have been prospected. The mineralization extends across wide zones, but channel samples show only low percentages of copper. On the Vedo and Robertson claims a mineralized zone has been traced for 3000 feet in length.

Tartan and Thompson Lakes. North of the North Arm of Athapapuskow, discoveries of copper pyrites have been made east of Tartan Lake and on an island at the south end of Thompson Lake.

Naosap Lake. This lake lies west of mile 22 of the Cold Lake railway branch. It is at the contact between the greenstone and the granite. A good deal of prospecting has been carried on in the region and some interesting discoveries have been made.

COPPER LAKE AREA

This area. around Copper and Brunne lakes, has been prospected for gold more particularly (See **Gold** p. 63) but zones of schist have been found mineralized with pyrite, pyrrhotite, copper pyrites, and zinc blende. One of these carrying values in copper and

zinc has been considerably developed by **Ventures Limited.**

HERB LAKE AREA

Herb Lake is also called **Wekusko Lake** (See **Gold** p. 66). Prospecting in the area has been directed mostly to gold, but some recent discoveries of sulphide zones are promising. One of these, at the south end of the lake, is being developed by **Manitoba Basin Mines Ltd.** The same company is exploring a copper-zinc ore deposit near **Reed Lake** which lies west of Herb Lake.

AREAS EAST OF HUDSON BAY RY.

Interesting discoveries of copper-zinc ore have been made at Cross, Oxford, God's, and Island lakes, and some of these are being explored by diamond drilling. Good values in copper, silver, and gold are reported across a width of 20 feet on the Adair-Mattson claims on Oxford Lake.

KISSISSING OR COLD LAKE AREA

Kississing or Cold Lake is about 45 miles northeast of Flin Flon Lake and 15 miles east of the Manitoba-Saskatchewan boundary. The Sherritt-Gordon property, on the south side of the lake, is connected with the Hudson Bay railway by a branch that leaves the Flin Flon branch near Cranberry Junction. The characteristic rocks of the area are gneisses of sedimentary origin, some of which are acid, having been derived from quartzite, while others have been derived from less acid and from basic rocks. These now appear as gray quartz-biotite-garnet gneiss and black hornblende-

garnet gneiss. The latter forms the hanging wall of the Sherritt-Gordon deposit. These rocks are intruded by granite, aplite, and pegmatite, and it is thought that these intrusions are responsible for the mineral deposits. The Kississing formations are very much like the Grenville series as seen in Eastern Ontario and Western Quebec. In the Parry Sound area of Ontario, gneisses similar to those of the Cold Lake or Kississing area show sheared zones mineralized with copper pyrites and zinc blende. In one of these zones garnets are very plentiful.

The copper-zinc sulphides deposits of the Cold Lake area are replacements of the gneiss in sheared and fractured zones. In many cases these zones are along the contact between quartzite-gneiss and hornblende-gneiss. The sulphides are pyrrhotite, zinc blende, and copper pyrites. A fourth rather uncommon sulphide, chalmersite, is also abundant. It is a magnetic sulphide of copper and iron. Galena occurs only sparingly. Assays show small values in gold and silver. These deposits differ from those of the Flin Flon and other areas farther south in two respects. The southern deposits are found in schisted lavas, and in them pyrite is the abundant sulphide of iron. There are numerous barren bodies of pyrrhotite throughout the Cold Lake area, revealing themselves by brownish or yellowish outcrops. The copper-zinc-bearing deposits are confined mostly to those parts of the area that are north and northwest of the tongues of granite from the granite batholith south of the area. The ore zones are commonly closely associated with dikes and other masses of pegmatite.

The frequent occurrence of barren pyrrhotite deposits makes it desirable to have some marks of distinction between the outcrops of these bodies and of the copper-zinc ore bodies particularly as the gossan covering the sulphides is often many feet deep. The gossan varies in color from yellow to brick-red. Where copper pyrites has been present in the original sulphides there are patehes of maroon or purplish brown color. Another reliable mark of gossan covering sulphides containing copper pyrites is the presence of small cavities lined with the dark purplish brown stain.

Sherritt-Gordon Mine. The ore body of the Sherritt-Gordon is near the east shore of the southeast bay of Cold Lake. It is a long, narrow zone of fractured and sheared quartzite-gneiss with fillings and replacement of pyrrhotite, zinc blende, chalmersite, and copper pyrites. In places, bodies of pegmatite completely fill the shear zone, emphasizing the close connection between the pegmatite and the deposition of the sulphides. The gangue minerals mixed with the sulphides are quartz, feldspar, hornblende, biotite, and garnet, with other silicates in less abundance. The mineralization has a probable length of over 2½ miles, and it has been definitely traced for 5300 feet of this by surface work. Diamond drill holes have intersected ore in the spaces between and beyond those explored by surface work. The ore body has been developed from two shafts about 7000 feet apart. Drifts from the east shaft showed ore from 14 to 50 feet wide, carrying 3.25 per cent of copper, 7 per cent of zinc, and about $1.00 in gold and silver. The west shaft and drifts

showed ore 22 to 30 feet wide, and averaging 2.3 per cent of copper and 3 per cent of zinc. Diamond drill cores show higher copper contents at the northwest end of the ore zone than elsewhere. These operations have proved the ore zone for a length of 12,000 feet in two shoots with a gap of 3000 feet between them still to be investigated. A third shaft has been sunk to 500 feet, and this is to be the main working shaft. In the first annual report, the amount of ore indicated is stated as 5,254,575 tons.

Other Discoveries. The majority of the copper-zinc deposits so far discovered are in a band about 10 miles wide extending northwest about 25 miles from the Sherritt-Gordon, but some discoveries have been made east of this near Elkan and Walton lakes, and copper-zinc sulphides have been found near Kipahigan Lake in the northwest corner of the area. The Dan Mac claims, just northeast of the Sherritt-Gordon, are being diamond-drilled by **Scotia Manitoba Mines Ltd.**

REINDEER LAKE AREA

Reindeer Lake is mostly in Saskatchewan, but the eastern part of it lies in Manitoba. The mineralization characteristic of the Cold Lake area extends northward to and beyond Reindeer Lake, and interesting discoveries of copper-zinc minerals have been made in the more northern region. The older rocks of the area are schists and gneisses of sedimentary origin, with small amounts of impure crystalline limestone and banded iron formation. These older rocks are intruded by granitic rocks including granodiorite, and by quartz diorite. There are also diabase dikes,

the youngest rocks of the area. The **Brown** mineral claims are on Pakwachi Bay, on the Manitoba-Saskatchewan boundary. The claims are owned by **The Reindeer Lake Syndicate, Limited.** The ore minerals are pyrrhotite, pyrite, zinc blende, copper pyrites, and galena. The chief values are in zinc, with less in copper, and still less in silver, gold, and lead. The Reindeer Lake area is about 45 miles north of the Cold Lake area.

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Sulphide Deposits at Flin Flon and Schist Lakes, Manitoba, Canadian Mining Journal, 1916, p. 468.

NICKEL

A description of the principal nickel minerals will be found at pages 6 and 7. While pyrrhotite has been the principal nickel-bearing mineral in Ontario, it is exceptional for pyrrhotite to carry more than a trace of nickel. Most of its occurrences in Ontario outside of the Sudbury region, and in Quebec and Manitoba have proved to be too low in nickel to be of economic importance.

Pentlandite and polydymite are apt to be overlooked when mixed with pyrrhotite and pyrite, but the coppery red color of niccolite and breithauptite makes them conspicuous. When nickel minerals weather, the products are apt to be of a green color, of a different shade from the green of copper stains. The colour may be completely obscured by the iron rust resulting from the weathering of iron sulphides, but the green of gar-

nierite, a silicate of nickel and magnesium, or of annabergite, arsenate of nickel, may guide to a discovery.

In the Oiseau-Maskwa area of Southeastern Manitoba there are a number of sulphide deposits that are much like those of the Sudbury copper-nickel region in Ontario. The characteristic sulphide is pyrrhotite, with smaller amounts of copper pyrites (See **Copper,** p. 80). The deposits are closely associated with intrusions of gabbro, but perhaps more so with granite intrusions. The nickel in these deposits runs from 0.5 per cent to 4 per cent. The ore bodies are small compared with those of the Sudbury region and could hardly compete with them under present conditions. The **Devlin-Chance** deposits are examples of ore bodies containing commercial percentages of nickel. They are about ½ mile north of Oiseau River and 2½ miles west of Oiseau Lake. The ore bodies are in andesite lava near a granite contact. The lava is intruded by bodies of gabbro and peridotite. The sulphide zones vary in width from 2 to 75 feet or more, but the sulphides occur in lenses from 2 inches to 2 or 3 feet in width and from 15 to 100 feet long. Scattered spots and pockets appear in the neighborhood of these lenses of solid sulphide. The nickel content of the ore varies from 0.27 per cent to 2.92 per cent. Copper pyrites and chalmersite occur sparingly in the pyrrhotite. Copper varies from 1 per cent to 2.6 per cent.

Assays of samples from deposits near Maskwa River show nickel, from ¼ per cent to 1½ per cent.

The sulphide deposits near West Hawk and Falcon

Lakes in the Boundary District carry only a trace of nickel.

In Northern Manitoba, pyrrhotite deposits are numerous, particularly in the Cold Lake area and northward. Many of these deposits are large and their conspicuous gossan cappings have attracted a good deal of attention from prospectors. So far as they have been tested they are barren of nickel. Their rock associations resemble those of the pyrrhotite deposit of Eastern Ontario and Western Quebec where rusty zones covering bodies of barren pyrrhotite are common in the sedimentary gneisses and schists of the Grenville series.

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COBALT

Cobalt is a constituent of a large number of minerals, and the high price of the metal and its oxide makes it profitable to extract them from a number of ores as chief products or as by-products. The silver ores of Northeastern Ontario carry considerable percentages of cobalt, principally in the minerals smaltite, chloanthite, and cobaltite. **Smaltite is** composed of cobalt, 28. 2 per cent, and arsenic, 71.8 per cent. Chloanthite is the corresponding nickel, mineral, which however carries more or less cobalt, so that the two

minerals grade into each other. **Cobaltite** is composed of cobalt, 35.5 per cent, arsenic, 45.2 per cent, and sulphur 19.3 per cent. More or less of the cobalt is replaced by iron, and the nickel mineral, gersdorffite, corresponding to cobaltite, sometimes carries important amounts of cobalt. The same is true of the iron-arsenic-sulphur mineral, **mispickel,** a variety of which **danaite,** carries from 3 to 9 per cent of cobalt. Pyrite sometimes carries cobalt. When the cobalt-arsenic minerals weather they form a pink mineral, **erythrite,** or **cobalt-bloom,** composed of cobalt, arsenic, oxygen, and water. This mineral appears as pink coatings and crusts over smaltite and other cobalt arsenides, and has served as a guide in prospecting for silver veins in Northern Ontario and in a similar territory in Quebec east of Lake Temiskaming. The association of silver with the cobalt minerals, while very general in that district, is not invariable. Veins of smaltite etc., have been found so low in silver as to be useless as silver ore. If the veins are large enough, they can be profitably mined for cobalt and arsenic. Nickel arsenides by weathering form a green mineral, annabergite, and when both cobalt and nickel are present in the mineral, the pink of erythrite may be masked by the green of annabergite. The result is often a white or light gray coating. Erythrite coatings and stains may appear as the result of small and scattered grains of smaltite, etc. It has often been observed in diabase dikes and other situations where the quantity of cobalt minerals was insignificant.

Uses. The metal is used as a constituent of a number of alloys. **Stellite** alloys are made from cobalt and

chromium, with the addition of tungsten and sometimes of other metals. One group of alloys has cobalt, 50% to 60%; chromium 40% to 30%; tungsten, 20% to 8%. Stellite alloys are used for the manufacture of machine tools, cutlery, surgical and dental instruments, evaporating dishes, annealing dishes, ornamental metal work, valves, plumbing fixtures, pens and combs. The silvery white color, stainlessness, and great hardness (some varieties are harder than quartz) fit it for these uses. Cobalt steels, made by adding small percentages of cobalt to steel, have superior properties for the manufacture of permanent magnets, including decrease in the size and weight of the magnets. Some applications of permanent magnets are possible only with cobalt steel magnets. **Cobalt oxides** are used for making the fine permanent blue color, **smalt blue** or **cobalt blue.** This is done by melting the oxide with a kind of glass and grinding the melt to a fine powder. **Cobalt salts** (oleate, etc.) are in growing demand as paint dryers.

No commercial deposits of cobalt minerals have been found in Manitoba. Cobalt bloom has been found in quantity northwest of the northeast arm of Schist Lake, in the Flin Flon area, where it has been formed by the weathering of smaltite disseminated in the schist. Cobalt bloom has also been noticed between Oiseau Lake and Winnipeg River. Mispickel is a characteristic mineral of Southeastern Manitoba, and it sometimes carries enough cobalt to give the conspicuous pink color when it is weathered. A sample from one of the sulphide deposits on the Chance claims in the Maskwa River area showed a trace of cobalt.

A little cobalt bloom has been noticed in the gossan over the Laurie sulphide deposit about half a mile southwest of Winnipeg River in Section 16, range 16, township 16.

IRON

Introduction. Only a few of the many iron minerals are used as ores of iron, namely, the oxides and the carbonate. The ore most commonly used is **hematite,** the pure mineral containing 70% of iron with 30% of oxygen. Next in importance is **magnetite** with 72.5% of iron and 27.5% of oxygen. **Siderite** is carbonate of iron, the pure mineral carrying 43.3% iron. There are complex carbonates of iron, magnesium, etc., such as ankerite, sometimes used as iron ore. **Limonite,** sometimes called **brown hematite,** is hydrated hematite. When it is heated, it loses water, and hematite is left. The pure mineral carries 59.9% of iron. When is is found in a loose condition at the bottoms of bogs or lakes, it is called **bog ore** or **lake ore.** Deposits of this kind are often found beneath the soil in places formerly bogs or lakes but drained by some natural change in the conformation of the surface. There are several varieties of iron ore that in composition come between hematite and limonite.

To be economically useful iron ore must fulfil certain conditions of purity, quantity, and accessibility. The average percentage of iron in the ore charged into blast furnaces on this continent is about 51%. A certain amount of ore containing less iron than this is sometimes mixed with richer ore, but, in general, ore

that carries less than 50% of iron must be concentrated, if it is to be used. The ore must be low in sulphur and phosphorus because these elements impair the quality of iron and steel. While it is possible to eliminate them, the sulphur by preliminary roasting and the phosphorus by a modification of the process of steel-making, these purification processes cost something, and so the presence of the impurities decreases the value of the ore. On the contrary, when the iron is to be used for making ordinary castings such as stoves, a certain phosphorus content is sought in the ore, as the resulting pig iron melts more easily, and makes a better casting. The "Bessemer limit" for phosphorus is .01% for every 10% of iron in the ore. For example, if an ore containing 55% of iron carries more than .055% of phosphorus, it is not admissible for making steel by the ordinary Bessemer process. More than a small percentage of titanium in the ore is considered objectionable because of difficulties that have been experienced in smelting high-titanium ore.

Small deposits of iron ore, no matter how good in quality, may be of no economic value, because it would not pay to mine them in competition with larger deposits. There is an especial difficulty in getting a market for small quantities of iron ore, because the users wish to run their furnaces with ore of known quality. When a new source of supply is offered, it is looked at coldly, even when the quality is good, unless a large annual tonnage can be guaranteed.

Accessibility is a very exacting requirement in the case of iron ore. The price is so low, $5 to $6 a ton

delivered at or near the furnaces, that the transportation costs must be correspondingly low.

Classes of Iron Ore Deposits. Iron ore deposits may be divided into classes (1) according to the composition of the iron minerals constituting the ore, or (2) according to the geological nature of the deposits. The first method of classification would give classes under the names, magnetite, hematite, etc. The second divides the ore deposits into the following classes:

1. **Vein-like deposits** of magnetite and hematite, usually as lenses at or near the contact of an igneous intrusion with the intruded rock.

2. **Segregation deposits** of magnetite and titaniferous magnetite, found at or near the outer edges of basic intrusives such as diabase and gabbro, and believed to have been derived from these rocks by separation during slow cooling from a liquid condition.

3. **Banded Iron Formation.** This consists of alternate bands of magnetite or hematite with chert, jasper or other varieties of silica. Sometimes both magnetite and hematite are present, and occasionally there are bands of siderite and pyrite. The iron minerals are sometimes mixed with the silica, and banding may not be visible. The bands of hematite and magnetite are sometimes very high-grade, but oftener they are mixed with enough silica to make them lean. Banded iron formation is thought to be of sedimentary origin.

4. **Secondary and Residual Deposits.** Under this head are put bog ore, and other deposits that have been formed either by the leaching out of iron from the rocks and subsequent deposition in a hollow, or by the removal of materials from a mixed deposit so as to

leave only the iron ore in place. In both these operations chemical changes of the substances have played a part.

Iron Ore Minerals

Hematite. The common variety of this ore is red hematite. All varieties are red when ground to a fine powder. The natural red hematite is fine-grained enough to have the color of the powdered mineral. It is often soft enough to powder with the fingers. When the ore is coarser grained and compact, it is steel-gray in color. When the crystals are still larger and show shining surfaces of a considerable size, it is called **specular ore** or **specular hematite.** When the crystals are small scales that easily separate and shine like mica, this ore is called **micaceous hematite.** Sometimes the ore has been deposited in rounded masses with a certain structure that suggests the name **kidney hematite.** Limonite sometimes has the kidney structure. Hematite is preferred as an iron ore because it is usually more porous than magnetite, allowing the reducing gases of the furnace to penetrate it more readily. This increases the speed of reduction and thus lowers the cost of smelting.

Magnetite. This ore owes its name to its strong attraction for the magnet, a property possessed only feebly by hematite. It varies in color from dark gray to black. When finely powdered, it is black. On account of its strong magnetic attraction, hidden bodies of magnetite can be detected by the deflection of the compass needle. The **dip needle** is swung on a horizontal axis and when correctly manipulated, it can

be used to measure in a relative way, the strength of the attraction. The **magnetometer** is a finer instrument used for the same purpose. It is possible by its use to survey a concealed body of magnetite and determine approximately its extent.

Limonite or **Brown Ore**. This is sometimes found in soft masses, or in cakes or grains, as a surface deposit. It is then called **bog ore**. Such deposits are usually too small to be of importance, but some large ones have been found. The ore has sometimes been altered by heat and then consists partly of dense, hard limonite, partly of hematite, and partly of **intermediate minerals,** particularly **goethite,** a brown mineral looking a good deal like limonite. Occasionally limonite is found in rounded masses suggesting the shape and structure of a kidney. It is then called **kidney ore** (see also **Hematite** p. 99).

Siderite. Also called **iron spar** and **spathic iron ore.** It is carbonate of iron containing, when not mixed with other minerals, 48.3% of iron. As found in nature, it is mixed with more or less of the carbonates of lime, magnesia, and manganese. All these are useful constituents of iron ore. The lime and magnesia act as fluxes for the silica present and so help to form the slag. Manganese improves the quality of steel. There are various mixtures of these carbonates with carbonate of iron that receive special names, the commonest being **ankerite.** Siderite, ankerite, and other minerals containing carbonate of iron are apt to show their presence at the surface by the rusty material formed when they are weathered. Some siderite deposits are fine-grained and of a gray color, but others are nearly

black. Well-crystallized siderite is like calcite in its cleavage, but is harder and heavier.

Important deposits of iron ore have not yet been found in the province, but there are large unprospected areas in which there are possibilities. The banded iron formation is represented in a number of areas, and, while the ore is lean, the great extent of such deposits where investigated in other provinces prompts the hope that economical methods of concentrating may be devised.

Lake Winnipeg

A deposit of turgite, sometimes described as hematite, occurs on the south shore of Black Island, at the north end of the southern expansion of Lake Winnipeg. Turgite is much like hematite, but it differs in composition, and may be described as hydrated hematite. The deposit occurs in sericite schist, in bunches, spheres, and also disseminated. It has been traced for 300 feet along the shore, but its total extent has not been determined. The ore is lean and probably high in sulphur.

Banded Iron Formation

Bodies of banded iron formation are found on Knee Lake, north of Falcon Lake and in the Upper Manigotagan area. The deposit north of Falcon Lake consists of magnetite banded with quartz. This ore may be capable of magnetic concentration.

Riding Mountain

On the north side of the mountain is shale with nodules of siderite, but not sufficiently concentrated for iron ore. Similar material is found in the valley of the

Assiniboine River. A specimen from White Sand River contained 34.07 per cent of iron.

Ochre

Yellow and red ochre occurs at a number of places in the Paleozoic limestones, for example, north of Moose Lake. It has been used as paint.

Clay Ironstone

Clay ironstone, a mixture of siderite or hematite with clay, etc., occurs on the Pembina and Souris rivers.

References: The Mineral Resources of Manitoba by R. C. Wallace, Industrial Development Board of Manitoba, Winnipeg, 1927.

Report on the Geology of the West Shore and Islands of Lake Winnipeg, by D. B. Dowling, Geological Survey of Canada, Part F. Annual Report, 1889.

Report on Explorations on Churchill and Nelson Rivers and around God's and Island Lakes, by Robert Bell, Geological Survey of Canada, Report of Progress, 1878-79, Part C, p. 36.

CHAPTER V

METALLIC MINERALS (Cont'd)

LEAD, ZINC, CADMIUM

LEAD

Introduction. The principal ore of lead is galena, the sulphide. It is very much the same in color as bright lead, but when very fine-grained, it is much darker. Galena is quite soft, which distinguishes it from some varieties of specular hematite that may be mistaken for it. When finely powdered, galena is gray, while hematite is brownish red. Galena is among the heaviest of minerals, having a specific gravity of 7.5. The pure mineral contains 86.6% of lead. When this fact is considered along with the high specific gravity of the mineral, it is seen that a relatively small bulk of galena scattered through gangue will give the minimum of 5 to 7% of lead necessary for profitable extraction.

In addition to galena, the carbonate of lead, **cerussite,** and the sulphate, **anglesite,** are sometimes found in sufficient quantities to be of economical importance, but as these minerals are usually products of

the weathering of galena, they are not likely to occur in quantity in a glaciated country like Manitoba.

Galena occurs with other metallic minerals in veins and similar deposits in various kinds of rocks, but deposits of galena workable for lead alone are the exception. The lead mineral is usually accompanied by zinc blende, and often by pyrite, coppper pyrites, etc. A great deal of the lead of commerce is produced from these complex ores along with other valuable constituents. Ores formerly rejected because of the difficulty of separating the lead, zinc, copper, etc., are now treated by oil flotation and modern smelting processes, so as to recover all the valuable constituents.

Galena carries more or less silver, and when the quantity is as much as 10 or 15 ounces a ton or more, the ore is called **silver-lead** or **argentiferous galena**. In complex lead-zinc-copper ores, the smelters pay for as low as 2 ounces of silver per ton. Some deposits of galena are very high in silver, and the silver value may be so great as to make the ore essentially a silver ore. A discovery of galena, even if the deposit is a small one, should be assayed for silver.

When the lead ore is accompanied by little or no zinc or copper ore, it is very easily smelted, and the required equipment is comparatively simple. When the ore is more complex, the necessary equipment for reducing it is correspondingly extensive. For this reason, a small deposit of complex ore may not be profitably workable, when it would pay to work a simple galena deposit of the same size.

Kinds of Deposits. The composition of a galena deposit is influenced not only by the rock in which it is placed, but by the natural process which has effected the concentration of the mineral. If the galena has been deposited in limestone with calcite, fluorspar, and barite, it is less likely to be accompanied by other ores than if deposited with quartz in association with an intrusion of igneous rock. It is usual to distinguish two main classes of deposits:

1. Those due to the after effects of igneous intrusions.
2. Those not obviously connected with igneous intrusions.

Those of the second class may have been caused by igneous intrusions, but the deposition has taken place so far away from the hot mass as to permit of a natural sorting that has left the galena to be deposited pretty much by itself. The deposits of the first class are more likely to carry silver than those of the second.

Galena-zinc blende deposits have been found in a number of localities, the lead mineral being usually a minor constituent of a complex mixture of sulphides. In the Oiseau River District, the **Cup Anderson** deposits carry an appreciable quantity of lead (See **Copper** p. 79). In the same area, on the **Beaver-Diabase** claims, north of Oiseau River, shear zones in schisted black andesite are mineralized with copper pyrites, zinc blende, and galena. A selected specimen of the ore assayed 2.50 per cent of lead and 6.10 per cent of zinc.

On the **Little Herb River,** at the north end of Herb (Wekusko) Lake, in Northern Manitoba, galena occurs in flat-bedded quartzite as a replacement deposit which apparently extends downward only 15 feet. In places the galena is mixed with zinc blende, and stibnite. The ore carries values in silver.—Near Puella Bay, on the southeast side of Herb Lake, it is reported that a long vein of lead-zinc ore has been discovered. — Considerable quantities of galena and zinc blende with quartz occur on the south shore of Snow Lake, Wekusko area, in a shear zone in greenstone.

Several discoveries of lead ore have been reported from the country through which the Hudson Bay railway has been built, and good samples have been brought out, but the commercial importance of these finds is not yet proved.

In the **Cold Lake** area, on the Ruby property of Cold Lake Mines, Ltd., a galena vein has been discovered. The ore is reported to be of commercial grade.

The ore of the Brown claims in the **Reindeer** area contains a little galena.

ZINC

The common association of lead ore and zinc ore has made it necessary to refer frequently to zinc blende in describing deposits of lead ore. These descriptions are not repeated here; but as there are a number of deposits in which zinc blende is the chief mineral they are described under the head of zinc.

The chief zinc ore mineral is **zinc blende** or **sphalerite** composed of zinc, 67%, and sulphur, 33%. It is

usually of a brown to black color, and the black variety is often called **black jack.** The darker varieties contain more or less iron, and the black mineral containing 10% or more of iron is often called **marmatite.** The yellow variety may contain little or no iron, and it is valued as raw material for the manufacture of zinc white, an oxide of zinc. Black jack may carry gold and silver, and it sometimes contains mercury. Zinc blende may also carry a small percentage of the rare metal cadmium. Unlike most of the metal ores, zinc blende is a poor conductor of electricity, and so does not respond to methods of exploration that depend upon the conductivity of the minerals sought. Other zinc minerals are the carbonate, **smithsonite, a** hydrated silicate, **calamine,** the oxide, **zincite,** and **gahnite**, a compound of zinc oxide with aluminum oxide.

The almost constant association of zinc blende with galena results in the usual production of lead and zinc from the same ore body (See **Lead** p. 105).

Zinc-lead ore occurs on the **Beaver-Diabase** claims in the Oiseau River area, a grab sample from which assayed 6.10 per cent of zinc.

The galena deposit on **Little Herb River** is mixed with zinc blende in places. In one trench the ore exposed assays 30 per cent of zinc. The discovery near Puella Bay, Herb Lake, is a lead-zinc deposit.

The **Flin Flon** ore carries 3.49 per cent of zinc, which will be recovered with the copper (See **Copper** p. 82). The rich copper ore taken from the **Mandy** mine carried a considerable proportion of zinc, which was not recovered because the difficulty in separating copper

from zinc in concentration and smelting operations had not been overcome when this rich ore was taken to Trail, B.C., and smelted there. The leaner ore remaining in the Mandy Mine contains important quantities of zinc (See **Copper** p. 83).—The copper deposits at Cranberry, Beaver, Copper, Reed, Vamp, Cross, Oxford, God's, and Island lakes, all carry zinc as zinc blende. Any of these that may be developed into copper mines will also produce zinc. — The Sherritt-Gordon ore averages 7 per cent of zinc (See **Copper** p. 83), and the other sulphide deposits being developed in the Cold Lake area carry zinc as well as copper.

The ore of the **Brown** claims in the Reindeer Lake area on the Manitoba-Saskatchewan boundary is a zinc-copper ore with smaller proportions of lead, silver, and gold.

It is seen from these data that many of the copper ore deposits in Manitoba will produce more zinc than copper. The higher price of copper attracts attention to that metal. The annual production of zinc from the Flin Flon and the Sherritt-Gordon will be very large, and as other deposits are brought to production, Manitoba will advance to the front rank as a producer of zinc.

CADMIUM

Cadmium is a rare metal found only in small quantities in ores of zinc, lead, and copper, and occasionally as the mineral **greenockite,** sulphide of cadmium. This mineral is of a bright yellow color, and is sometimes noticed as stain and coatings on zinc ores. Ana-

lyses of zinc blende have not so far shown as much as 5% of cadmium. The chief source of cadmium is the flue dust of zinc, lead, and copper smelters. In the purification of zinc by distillation of the metal, cadmium, having a lower boiling point than zinc, distils with the first portions of zinc, and the two metals oxidise and form a dust, which is used as a source of cadmium.

Cadmium is a soft metal of about the color of steel. Its uses are in making anti-friction and other alloys. Its most important use is in alloying to the extent of one per cent with copper to be used in making trolley wire. It increases the resistance of the copper to wear. The demand for cadmium is increasing.

When zinc smelters and refineries are in operation in Manitoba, cadmium will probably be a by-product.

CHAPTER VI

METALLIC MINERALS (Cont'd)

STEEL ALLOY METALS

CHROMIUM

Chromite, the only ore of chromium, is a black mineral usually found in serpentine, but also occurring in peridotite and other basic igneous rocks. Other favourable places are the edges of basic intrusions such as norite and gabbro. Valuable chromite deposits have been found in such situations in other countries.

Chromite is composed of chromium, iron, and oxygen. It is used to make ferro-chromium for the manufacture of chromium steel and stainless steel. Pure chromium is extracted from chromite and alloyed with cobalt and other metals to make the stellite alloys. **Nichrome** is an alloy of nickel and chromium. Pure chromium is used for electroplating certain parts of machinery.

The greater part of the chromite mined is used in the manufacture of refractory linings for furnaces, and for making a number of chemicals, some of which are the basis for yellow, orange and other paints.

To be merchantable, chromite should contain not less than 50 per cent of chromic oxide. The pure mineral contains 68 per cent. Lean ores can sometimes be profitably concentrated. The deposits are mostly in the form of bunches and veins scattered in the serpentine.

Chromite has not so far been found in Manitoba. It may be discovered in areas where there are basic igneous rocks, particularly dunite, peridotite, and gabbro. It may also occur in serpentine. The dark green serpentine on Iron Island, Island Lake, and the accompanying deep green rock are probably colored by chromium.

MANGANESE

Manganese is a metal somewhat like iron. It has not been used by itself, but in alloys with iron and other metals. Its chief use is as a constituent of ordinary steel, up to 1%, and alloy steels. Hadfield steel contains 12% to 15% of manganese.

The ores of manganese are as follows:

Pyrolusite, a black oxide of manganese, containing when pure 63.2% of the metal.

Psilomelane, or **hard manganese ore,** of variable composition. It often accompanies pyrolusite.

Wad or **bog manganese** is a brown, soft, earthy mineral, variable in composition. It looks like bog iron ore ,but is darker in color. It sometimes accompanies pyrolusite.

Asbolite is a variety of wad carrying cobalt.

Rhodochrosite is carbonate of manganese. It is a pink mineral, like calcite in general appearance.

Pyrolusite and psilomelane deposits of economic importance are found mostly in limestone, sandstone, and shale of the later geological periods. They sometimes occur in chert, jasper, and quartzite. The chances of finding such deposits in the Precambrian rocks of Manitoba are not very good.

The only deposit of manganese minerals of possible economic importance so far observed in Manitoba is one of wad or bog manganese at the foot of the Pembina Hills four miles northwest of Roseisle, where it occurs at the base of the escarpment in low ground. The manganese ore is mixed with a considerable proportion of limonite. An analysis of the best looking material gave nearly 27 per cent of metallic manganese. The minimum requirement is 50 per cent, but ore is merchantable with less than this, if iron is present. The Pembina material contains about 13 per cent of iron.

Reference: The Mineral Resources of Manitoba, p. 37, by R. C. Wallace, Industrial Development Board of Manitoba.

MOLYBDENUM

Introduction. The principal ore of molybdenum is molybdenite, a sulphide of the metal. A second mineral, wulfenite, a molybdate of lead, has been used as an ore of molybdenum, but it does not often occur in commercial quantities. In parts of Manitoba where both molybdenite and lead ore are found, there may

be localities where the conditions for wulfenite deposits are present. The weathering of molybdenite forms a yellow product, **molybdite** or **molybdenum ochre,** and sometimes a gray mineral, powellite, molybdate of lime. Neither mineral is of any importance as ore.

Types of Deposits

Four types of molybdenite deposits are described:

(1) Segregations of pyrite, pyrrhotite, fluorspar, quartz, and feldspar, with molybdenite, in syenite.

(2) Veins of pyrite, pyrrhotite, and quartz in granite-gneiss.

(3) Pegmatite dikes and feldspar-quartz veins.

(4) Contact metamorphic deposits.

Something like 75% of the known occurrences of molybdenite are in acid igneous rocks such as granite, pegmatite, and syenite. It is rarely found except in association with intrusions of igneous rocks.

Depth of Deposits

There is an impression that the molybdenite diminishes at depth, but the evidence for this is by no means conclusive. The workings are mostly shallow, and on account of the irregular and scattered deposition of the mineral, diamond drilling, unless systematic and close-spaced, does not give conclusive evidence. The fissure-vein type of deposit is apt to persist with depth. At the Marble Bay copper mine, Texada Island, B.C., molybdenite was mined at a depth of 1000 feet.

Reduction

Molybdenum is made from molybdenite by reduction in the electric furnace, either directly or after oxidation. Its fusion point is 2500° centigrade, 745 degrees above that of platinum. It is very hard and commonly brittle, but a ductile variety is made. Its tensile strength when drawn into wires is about half that of tungsten wire.

Uses

For many years molybdenum has been used for making alloy steels. For this purpose ferro-molybdenum is first made by reducing molybdenum oxide with iron in an electric furnace .The Tivani Steel Company, Belleville, reduced the molybdenite directly, the concentrates being charged into the furnace with lime and coke. Ferro-molybdenum contains from 50 to 80% of molybdenum.

Molybdenum steel is made by adding either ferro-molybdenum or calcium molybdate to the melted steel. For high-speed tools, permanent magnets, self-hardening steel, rustless steel, stainless steel, etc., over 1% of molybdenum is used, the percentage for various purposes ranging from 1 to 10. For structural steel the percentage of molybdenum is less than 1%, and is usually 0.25%. Increasing quantities of this low molybdenum steel are used in the manufacture of automobiles. It is also used for pressed metal parts, railway forgings and track bolts, armor plate, air flasks, pneumatic hammers, agricultural implements, shovels, machinery forgings, piston rods, chains, pierced tubes, rolls, etc. In the manufacture of

low-molybdenum steels, othes metals such as nickel, chromium, and vanadium are added as well as molybdenum.

Molybdenum is a constituent of a number of useful alloys containing no iron (non-ferrous alloys), such as stellite, the main constituents of which are chromium and cobalt, **chrome-molybdenum,** etc.

In addition to these large uses, molybdenum is used for a number of purposes for which the pure metal is required, including lamp filament supports, winding for electric resistance furnaces, contact making and breaking devices, spark plug points, X-ray apparatus, voltage rectifiers, thermocouples, arc lamp electrodes, plates used in wireless telegraphy, and in dentistry and jewelry. For some of these purposes it takes the place of the much more expensive metal, platinum. A considerable quantity of molybdenite is required for the manufacture of a number of molybdenum chemicals used in chemical analysis, fire-proofing of fabrics, disinfectants, coloring of pottery, dyeing of cloth, silk, wool, leather, rubber, etc., and for a number of other purposes.

Boundary District

FALCON LAKE

Molybdenite occurs in a number of places in the Boundary District. In several parts of this district pegmatite dikes are common. They are of two types, dikes of a tabular form running with the strike of the schists in which they lie. These are the commonest kind of dikes. The second kind is irregular in form and the pegmatite cuts across the strike of the schists.

Molybdenite is the prominent metallic mineral in these pegmatites. It occurs mostly in crystals from ½ inch to 3 inches in diameter. Bunches of these crystals up to 20 pounds in weight have been found. Fine grained molybdenite is present, but not plentifully. The best deposits are about 2 miles north of the west end of Falcon Lake, where the pegmatite dikes are in schists near the granite contact. During the Great War, a good deal of work was done on a number of claims in this area, most of it on the **Gull** and **Tom Boy** claims.

STAR LAKE

Molybdenite occurs with bismuthinite in quartz-pegmatite vein-dikes near the granite contact west of Star Lake. The molybdenite is more abundant in the quartz than in the pegmatite. These structures are considered to be a transition from pegmatite dikes to quartz veins.

HIGH LAKE

Quartz veins carrying considerable amounts of molybdenite occur near High Lake and the east end of Falcon Lake. The mineral is found in irregular masses, narrow veins, and groups of parallel stringers of quartz that occur in shear zones of felsitic and porphyritic rocks near the contact of schists with granite. In places the quartz carries as much as 5 per cent of molybdenite.

Oiseau River District

LAC DU BOIS

Molybdenite occurs in pegmatite at a number of places west of Point du Bois. About a mile west of Lac du Bois and ¼ of a mile north of the City of

Winnipeg railway, a prospect pit has been sunk in pegmatite at a granite-andesite contact. The molybdenite is in small pockets and bunches along the contact for about 200 feet and across a width of 2 inches to 2½ feet.

Northern Manitoba

HERB LAKE

On the west shore of Crow-Duck Bay, Herb (Wekusko) Lake, molybdenite occurs in a pegmatite dike in sufficient quantity to have warranted some mining with war-time prices ruling. Molybdenite occurs in small quantities in quartz veins on the north arm of Little Herb Lake.

PHANTOM LAKE

Quartz veins near Phantom Lake in the Flin Flon area show notable quantities of molybdenite. The not infrequent occurrence of this mineral in quartz veins in Northern Manitoba is in itself only of mineralogical interest, but the widespread occurrence of the mineral prompts the hope that it may be found in commercial quantities as at Kewagama Lake in Quebec.

NELSON RIVER

Molybdenite occurs with pyrite and magnetite in pegmatite dikes near the north end of Little Playgreen Lake, which is near the outlet of Lake Winnipeg.

References: Geology and Mineral Deposits of Oiseau River Map Area, by J. F. Wright, Geological Survey of Canada, Summary Report, 1924, Part B, p. 99.

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TITANIUM

Introduction

Titanium is widespread in the earth's crust, forming about 0.44% of the total as far as known. The chief minerals occurring in commercial quantities available for the manufacture of titanium products are the oxide of titanium, **rutile**, containing 59% of titanium, and **ilmenite,** an oxide of titanium and iron, of variable composition, but containing theoretically about 31.5% of titanium. Deposits of rutile of commercial importance are very rare, there being only four deposits at present known, at Kragero in Norway, in Nelson County, Virginia, at St. Urbain, Quebec, and at Mount Crawford, South Australia. In addition to these sources, a little rutile is produced by the washing of sands, for example, along with monazite, zircon, etc., at Pablo Beach, Florida. Deposits of ilmenite are much more numerous and widespread. A great many deposits of iron ore contain titanium, and when the amount of this element is above 2 or 3%, the iron ore is not acceptable at the blast furnace. On the other hand, ore containing less than 15 to 18% of titanium is not at present acceptable for the manufacture of titanium products. As there are many bodies of magnetite mixed with ilmenite in various proportions, there is a wide range of **titaniferous**

magnetites for which there is at present no demand, namely those containing from 3% to 15% of titanium. (The percentage of titanium is often stated as **titanic acid** or **titanium dioxide** or TiO_2. To convert this into the percentage of titanium, it is only necessary to multiply by 6 and divide by 10. To convert percentage of **titanium** to percentage of **titanic acid,** multiply by 10 and divide by 6.) The Norwegian ore of titanium carries from 25 to 45% of titanium dioxide equal to 15 to 27% of titanium.

The market price for rutile is 10 cents a pound for rutile carrying 94% of titanium dioxide, and for ilmenite $9.50 to $11 a ton for ilmenite carrying 52% of titanium dioxide, nearly pure mineral. For 32 to 35%, $7 to $8 a ton.

Uses

The uses of titanium products are numerous and growing in importance, but the amount of ore required to meet the present demand is small, probably not more than 15,000 to 20,000 tons a year of rutile and ilmenite combined. The principal products, requiring by far the greater part of the ore produced, are **ferrotitanium** and **ferrocarbontitanium** used in the purification of steel, and, of late years, **titanium white,** a substitute for white lead in the manufacture of white paint. **Ferrotitanium** is made from ilmenite by the thermit process, that is, by reducing with aluminum at the high temperature caused by touching off a mixture of the ground ore with powdered aluminum. The aluminum is oxidised at the expense of the ore in which both iron and titanium are deprived of their oxygen. The product contains about 25% of

titanium. **Ferrocarbontitanium** is made by reducing ilmenite with coke in an electric furnace. The product contains 15 to 18% of titanium and 5 to 9% of carbon. It sells for $160 a ton.

The addition of a small percentage of titanium to manganese steel and nickel steel is said to improve their forging qualities.

Cuprotitanium is made by reducing rutile in an electric furnace in a bath of aluminum to which copper has been added. The aluminum removes the oxygen from the rutile and the titanium alloys with the copper. The product is used to improve the quality of copper for making copper castings.

Manganotitanium, made by the thermit process, has been proposed as a deoxidiser of bronze in castings.

Titanium carbide, made by reducing titanium dioxide with coke in an electrical furnace, is an extremely hard material used in the manufacture of **arc light electrodes.** Ilmenite and rutile are used for the same purpose. In the **magnetite lamp,** the cathode is made of magnetite with 15 to 20% of rutile and a certain amount of chromite. The magnetite is used because of its conductivity for electricity. Rutile and other titanium compounds are found to be superior to all other materials in giving efficiency to the light.

Metallic titanium is difficult to manufacture pure. Hunter's method of reducing titanium tetrachloride with metallic sodium gives the pure metal, but is too costly for commercial purposes. Electric lamp filaments made of titanium give a white light of great efficiency and will probably come into use as soon

as a suitable method of manufacture is found. The impure metal, 80 to 90%, sells for $5 a pound.

Titanium white or **titanox** is pure titanium dioxide made from ilmenite by a process that makes the product rather high-priced. In spite of this, its great superiority in covering power and durability gives it such an advantage over the older white paint materials that it is likely to come into general use. The absence of any poisonous quality gives it an additional advantage over white lead. Titanox is manufactured by The Titanium Pigment Company, Inc., at Niagara Falls, N. Y. It has been announced that a factory is to be built in Vermont to make titanium white from ilmenite. The Titan Company, of Norway, uses ilmenite containing 25 to 45% of titanium dioxide, equal to 15 to 27% of titanium. As the poisonous character of white lead is causing more and more uneasiness regarding its use as a paint, it is likely to be displaced by titanium white, which will then become the chief titanium product manufactured.

A number of titanium compounds are used as colors and mordants in the dyeing industry. Several pigments with a titanium base are used as colors for porcelain, including **titan yellow** made from rutile. Rutile is used to give the very pale yellow color to artificial teeth.

There is a wide range of titanium compounds, and as these are studied many of them will be found useful.

Ores

Rutile. This is natural titanium dioxide. It is a hard mineral usually red or reddish brown in color, but

sometimes yellowish, bluish, violet, black or green. The crystals are four-sided prisms. It is found as a constituent of a great variety of rocks, igneous, sedimentary and metamorphic, and also sometimes in veins. Though so common in rocks and veins, rutile rarely occurs in sufficient concentration for commercial purposes. Most of the known workable deposits are associated with gabbro or anorthosite. Some deposits in pegmatite dikes may be workable.

Ilmenite. Ilmenite is an oxide of iron and titanium of somewhat variable composition, but theoretically containing 52.7% of titanium dioxide, equal to 31.62% of titanium. It is a hard, black, heavy mineral. It looks much like magnetite, but is duller in lustre and only slightly if at all magnetic. It however often occurs intimately mixed with magnetite and a small proportion of the latter makes the whole mass distinctly magnetic. These mixtures of ilmenite and magnetite are rather common. As titanium ore they are not to be considered unless they contain at least 15% of titanium.

While ilmenite is a frequent constituent of basic schists, no deposits of commercial importance have been found in the province. The growing importance of high-titanium deposits should prompt careful watch for both ilmenite and rutile in those areas where basic intrusive rocks such as gabbro and anorthosite occur (**Anorthosite** is a variety of gabbro, very commonly of a white or light gray color, due to the absence of the black varieties of pyroxene). Rutile may also occur in workable quantities in pegmatite dikes.

Reference: Titanium by A. H. A. Robinson, publication No. 579, Mines Branch, Ottawa.

TUNGSTEN

The metal tungsten, once only a curiosity, has become of late years a valuable material for tungsten steel, also called wolfram steel, and as a constituent of other alloys. Tungsten steel is harder and tougher than ordinary steel. It is also self-hardening, so that tools made of it do not require tempering. On account of its high fusion temperature (5576° Fahrenheit) and its power of radiating white light, tungsten is extensively used in making the filaments of electric light-bulbs. Compounds of tungsten are used as mordants in dyeing and for weighting silk. They are also used in making cotton fabrics fireproof.

The principal tungsten minerals are as follows:

Wolframite, a tungstate of iron and manganese, is a very heavy black or brown-black mineral. It turns reddish brown when rubbed to a fine powder.

Huebnerite, a tungstate of manganese, is much like wolframite, is reddish brown in color, and is yellowish brown when finely powdered.

Ferberite is tungstate of iron. It is a heavy black mineral, rather soft, and powdering brownish.

Scheelite, tungstate of lime, is a heavy mineral of a creamy white, yellowish or light brown color. It looks somewhat like calcite or orthoclase, but is much heavier.

Tungstite is a decomposition product of the other tungsten minerals and occurs as stains or crusts of a

golden yellow color. It is seldom found in quantities of economic importance.

Tungsten minerals are found in the rocks with which tinstone deposits are associated, and also in quartz veins in gold regions. The tungsten minerals are sometimes found in quartz veins barren of gold, and sometimes in auriferous veins. As a rule, however veins rich in gold are poor in tungsten minerals, and those rich in tungsten minerals are poor in gold. Wolframite and huebnerite are easily distinguished in the quartz by their brown color, good cleavage, weight, and comparative softness. They are easily scratched with a knife, whereas quartz is harder than steel. Quartz veins carrying these minerals are apt to have the walls of cracks covered with a black coating, probably oxides of manganese, or possibly ferberite.

The tungsten minerals should therefore be sought in the gold fields of Manitoba, and also in those regions where granite intrusions have given rise to pegmatite dikes and irregular quartz veins that are looked upon as similar in origin to the dikes, as it were, dikes that happen to be composed altogether of quartz. These veins may be found at the edge of the granite or in the rocks intruded by the granite, such as gneiss, schists, and slate. The veins may occur in these rocks at considerable distances from the outcrops of granite. In south Dakota wolframite has been found associated with siliceous gold deposits in dolomite.

Scheelite has been found in an area northwest of Falcon Lake in Southeastern Manitoba. Falcon Lake lies south of Star Lake, near the Ontario boundary. The scheelite deposits are near the granite-greenstone

contact, and the mineral occurs in a fine-grained hornblende rock that has a somewhat sheeted structure. Quartz veinlets run with this sheeting. The scheelite is in lenses not associated with the quartz, but with epidote and smaller quantities of calcite and garnet. The scheelite is in small white or reddish crystals. It may be mistaken for the associated calcite, but the weight of a good specimen would attract attention. The scheelite lenses are 2 to 4 inches wide and a few inches to a few feet in length. Milling tests made on about 4 tons of ore at the Mines Branch, Ottawa, yielded 177 pounds of concentrates containing 70.63 per cent of WO_3. The ore carried 1.65 per cent of WO_3. (Geological Survey of Canada, Summary Report 1918 p. 14D).

VANADIUM

Vanadium is a rare metal found as a constituent of certain minerals but never native. It is not used as a separate metal, but mostly as a constituent of alloy steels. Large quantities of vanadium steel are used in the manufacture of automobiles and other structures in which a combination of strength with a small weight of steel is desirable. The use of vanadium steel would doubtless be much extended, if the supply were increased, but the vanadium minerals so far drawn upon are scarce, and it is said that the visible supply is nearing exhaustion.

Vanadium Minerals

Patronite is a sulphide of vanadium found in Peru mixed with a coaly substance. This has been the chief source of vanadium for a number of years.

Carnotite contains uranium and vanadium oxides (See **Radioactive Minerals,** p. 141). It has been used as a source of radium rather than of vanadium, the latter being only partly recovered. In Colorado and Utah it is found in sandstone. Its occurrence as a yellow incrustation on ilmenite and titaniferous magnetite is significant in view of the fact that these minerals carry a small proportion of vanadium.

Vanadium in Titaniferous Magnetite. Titaniferous magnetite is a mixture of magnetite with ilmenite (See **Iron** p. 98 and **Titanium** p. 122). So far as analysed for vanadium, the presence of that element seems to be pretty general in titaniferous magnetites. Vanadium was discovered in an analysis of the slag from iron furnaces working on the minette ores of the Alsace-Lorraine region. The proportion of vanadium in the titaniferous magnetites that have been examined for it is from about 0.1% to 0.45%. In ores high in titanium the analysis for vanadium is difficult, and its presence in the ore may be overlooked.

Vanadinite contains vanadium, lead, chlorine and oxygen. It is of a deep, ruby red color, sometimes reddish brown or yellow. It is soft and heavy.

Roscoelite is a variety of mica containing vanadium. Its color is brown or greenish brown.

Vanadium minerals have not so far been found in Manitoba.

CHAPTER VII

METALLIC MINERALS (Cont'd)

ANTIMONY, ARSENIC, BISMUTH, MERCURY, TIN

ANTIMONY

The principal ore of antimony is the sulphide, **stibnite,** but native antimony and other antimony minerals are often found mixed with the stibnite.

Antimony is used as part of the alloys Babbit metal and type metal. A little is sometimes used to harden lead to make shot and bullets. Tartar emetic and a few other medicines are compounds of antimony.

Oxford Lake

Veins of solid stibnite occur in sericite schist at the west end of Oxford Lake, associated with quartz and calcite. Several tons have been selected for a trial shipment. Oxford Lake is at the headwaters of Hayes River which empties into Hudson Bay east of Port Nelson.

Herb Lake

Stibnite occurs in quartz veins on the east side of Herb Lake. It is also found in the zinc-lead deposits

on Little Herb River. These occurrences are not of economic importance.

Lake Winnipeg

A piece of native antimony float was found in 1921 near the east shore of the lake not far from the mouth of Sandy River. The source of the mineral has not been discovered.

Reference: Mineral Resources of Manitoba, by R. C. Wallace, Board of Industrial Development, Winnipeg, 1927.

ARSENIC

The principal ore of arsenic is mispickel composed of iron, sulphur, and arsenic. The substance usually called arsenic is a white powder, an oxide of arsenic. Arsenic itself is a tin-white material of metallic appearance, but too brittle to be considered a true metal. It is sometimes found in small quantities (native arsenic) with stibnite, in silver ores, and with other metallic minerals.

Deposits of mispickel are apt to be found in association with the less basic rocks such as diorite, or with acid rocks, like granite. It is most commonly found in quartz veins, which may carry gold in payable quantity. A good deal of the arsenic of commerce is recovered as a by-product in the treatment of ores of gold, silver, lead, and copper.

The percentage of arsenic required to constitute a payable arsenic ore independent of other valuable contents depends on the selling price of white arsenic, which varies through a wide range. Since 1921 the

limits have been 5½ cents to 16 cents a pound. For direct treatment arsenic ore must contain not less than 15 per cent of arsenic, and in the absence of other valuable constituents ore that requires concentration previous to treatment probably could not be made to pay with a content of arsenic less than 5 per cent.

So far as the production of arsenic goes as the chief product, the majority of occurrences of arsenic minerals are of no importance. The arsenic minerals are found at many localities in the province, and mispickel in particular is a common mineral. While its discovery in small amounts is unimportant, it should always be remembered that the exceptional concentration of the mineral in a large body may be found in the same neighborhood.

Mispickel usually weathers to a whitish or pale yellow crust, sometimes a little rusty. If it contains cobalt, the weathered material may be pink, **cobalt bloom**. Arsenides of nickel weather to a green nickel coating. Some of the arsenic minerals containing both nickel and cobalt weather nearly white, the green of the nickel bloom killing the pink of the cobalt bloom.

Uses of Arsenic

The tin-white metallic-looking element, properly called arsenic, is used in the manufacture of metal alloys. It has a hardening effect on soft metals like lead, tin, copper, and zinc, and therefore is used to give this property to lead shot, various bronzes, copper, bearings alloys, muntz metal, and the speculum metal (alloy of copper and tin) for the mirrors of reflecting telescopes. Indian fire is a signal light made by burning arsenic with some material giving a supply

of oxygen. When arsenic is exposed to the air for a long time, it oxidises to a gray powder, sometimes used as a fly poison.

By far the most important arsenic product is the oxide, white arsenic, produced by roasting the ores containing arsenic minerals and condensing the arsenical fumes in a "bag house" where the flue gases are filtered through a special kind of cloth. The purified product is used largely in the manufacture of insecticides, that is, preparations for killing insects that destroy agricultural crops. The chief of these are Paris green, calcium arsenate, and lead arsenate. Their use is extending fast and so increasing the demand for white arsenic that the price rises to a high point when the supply fails to keep up with the growing demand. Other arsenic preparations are used for sheep dips, and white arsenic itself is used to poison baits for grasshoppers and cutworms. There are a number of dyes and colors made with arsenic compounds.

WEKUSKO OR HERB LAKE

Mispickel (arsenopyrite) occurs in considerable quantities in gold-bearing quartz veins near Wekusko Lake, about 90 miles northeast of The Pas. The mispickel appears in the wall rock as well as in the veins. In places, the wall rock is almost solid mispickel for a width varying from a few inches to a foot. It might be recovered as a concentrate in mining for gold (See **Gold** p. 65).

STAR LAKE AND FALCON LAKE

Mispickel is found in considerable quantities in gold-bearing quartz veins near Star and Falcon lakes

which are a few miles from the Canadian Pacific railway between Winnipeg and Kenora. The area is not far from the Ontario boundary (See **Gold** p. 43).

SHATFORD LAKE

At Shatford Lake, about 11 miles east of Lac du Bonnet, is the Miller arsenopyrite prospect, which shows a mass of the mineral two feet wide in andesite. (Geological Survey of Canada, Summary Report, 1924, Part B, p. 98).

PIPESTONE LAKE

This lake is an expansion of the Nelson River north of Lake Winnipeg. Mispickel with pyrite occurs in schist on a large island near the point where the river enters the lake (Geol. Surv. of Canada, Summary Report, 1919, Part D, p. 18). The mineral has been reported at other places in the area, but the quantities seem to be too small to be of economic importance.

ELBOW LAKE

Elbow lake is about 80 miles north of The Pas. Mispickel is found in the wall rock of gold-quartz veins, but not in important quantities (Geol. Surv. of Canada, Summary Report, 1922, Part C, p. 41).

References: The Mineral Resources of Manitoba, by R. C. Wallace, Industrial Development Board of Manitoba, Winnipeg, 1927.

Arsenic-bearing Deposits in Canada, by M. E. Hurst, Geological Survey of Canada, publication No. 2131

BISMUTH

Bismuth is a rather rare metal, sometimes found native, but more commonly as the sulphide, bismuth-

inite. Both usually occur in complex ores of other metals such as gold, silver, and copper, and the bismuth is sometimes recovered from these ores as a by-product. Tetradymite is composed of bismuth and tellurium. Native bismuth is found in some gold and silver ores.

Uses. Bismuth is used in making easily fusible alloys (safety plugs, etc.,) and a number of medicinal substances.

Native bismuth occurs with lithium minerals in pegmatite dikes near Point du Bois on the Winnipeg River. It has also been observed farther north, near Cat Lake. Tetradymite, a telluride of bismuth, accompanies the gold ore of the English Brook area, Rice Lake district.

MERCURY or QUICKSILVER

The principal ore of mercury is the sulphide, cinnabar, which is usually red or brownish red, somewhat like red hematite, with which it has sometimes been found. The mineral is occasionally gray. It is found in veins in shale and slate, rarely in granite and porphyry. The copper ore, tetrahedrite, occasionally carries mercury in economic quantities. Native mercury is occasionally found in very small drops, usually with cinnabar. The price of mercury tends upwards, as old mines are becoming exhausted.

TIN

The chief ore of tin is **cassiterite** or **tinstone,** an oxide of the metal. It is a hard, very heavy mineral, and

these properties enable it to survive the wear when the rocks in which it is deposited break down. The tinstone is then concentrated, as gold is, in the sand and gravel. Placer tin deposits thus formed are the chief source of the tin ore of commerce.

Tinstone is found in granite country, particularly where the granite is in the form of coarse-grained dikes, pegmatite granite. In the vicinity of tin ore the granite is apt to be a white or gray variety called greisen, made up of quartz and white mica with little or no feldspar. The tinstone is sometimes in this rock, and sometimes in quartz veins, in pegmatite, porphyry, or in slate and other sedimentary rocks in contact with these igneous intrusives.

Cassiterite is rather hard to identify in the field. It is usually black or dark brown, but sometimes light brown or gray. Its great weight, specific gravity about 7, attracts attention if there is enough of it to make its weight felt. If a piece of tinstone is put in dilute hydrochloric acid with a little zinc, it becomes plated with tin.

The sulphide of tin, **stannite,** is sometimes found in important quantities, usually with cassiterite. It is steel-gray to iron-black, sometimes a little yellowish. It is not so heavy or so hard as cassiterite.

Ore containing from 1½ to 3% of tin can be profitably worked. Tin ore may be found in the same deposits with such radium minerals as uraninite.

Tin is in constant and increasing demand, and, as failing commercial deposits are not replaced fast enough by new sources of supply, the tendency of the

price is upwards. The present price (1929) of the metal is about 60 cents a pound.

Both cassiterite and stannite have been found in southeastern Manitoba in the area traversed by the Maskwa, Oiseau, and Winnipeg rivers. This area is characterized by intrusions of Algoman granite, doubtless parts of the same great batholith evident in the adjoining gold region in Ontario. There are numerous pegmatite dikes breaking through the granite and the schists that have been much altered and in many places highly mineralized with sulphides and minerals like tourmaline and apatite characteristic of tin ore deposits elsewhere. The earliest discovery was of the sulphide, stannite, reported by J. S. De Lury in 1919 as occurring in the large sulphide bodies near West Hawk Lake, close to the Ontario boundary. Small quantities of cassiterite were observed later in the lithium-bearing pegmatite dikes near Falcon Lake and Point du Bois. In 1925 K. E. Miller found good specimens of tinstone on a small rocky islet in Shatford Lake, a small lake south of Oiseau River, into which it drains. The cassiterite occurs in pegmatite composed mostly of quartz and white mica, the **greisen** of most tin-producing countries.

Later, tinstone was found near Bernic Lake, a few miles northeast of Shatford Lake, and promising discoveries have been made between the two lakes, and also between Bernic and Oiseau lakes farther to the northeast. Scattered discoveries of tinstone have been made throughout the area lying between the Oiseau River and the Winnipeg River to the south, but the most promising concentrations of the valuable miner-

al are being developed in the area that contains Shatford, Bernie, and Oiseau lakes, a piece of country about 10 miles long. Tourmaline is the mineral most commonly associated with the tinstone, and as both minerals are black, there is some difficulty in distinguishing them. Tinstone has been found not only in the pegmatite but also in narrow bands of garnet and other metamorphic rocks along the walls of the pegmatite. Some large bodies of sulphides in the district are reported to have yielded assays of tin, for example in the vicinity of West Hawk Lake. Bulk samples of ore from the Bernie Lake property of Jack Nutt Mines Ltd. gave from 1.5 to 2 per cent of tin. The samples ranged from 10 to 13 tons each. Concentration tests gave a fair recovery of concentrates. Such ore could be mined with profit under favorable circumstances.

"Most granites carry tin but few of them have been productive sources. Is there any evidence as to the richenss in tin of the Manitoba batholith? Such evidence is slowly accumulating and the promise is growing with each new find. Near West Hawk and its neighboring lakes there is some evidence that a great deal of tin came from the batholith. It is unfortunate that in this locality most of the tin seems to occur widely scattered as sulphide tin in masses of sulphides that are numerous and large. Between Winnipeg and Oiseau rivers, however, much of the ton occurs as the oxide. Enough finds have been made there to indicate that the batholith contained sufficient tin to have produced commercial bodies, should the proper local conditions have existed for a proper concen-

tration. The history of pegmatite in connection with tin production indicates that this type of occurrence is not commercially promising though it is a possible source. It can not be said that pegmatites are not worthy of thorough prospecting. Some of them have produced a little tin and many of them are so close to being producers that this type of deposit cannot be ignored. Then there is the possibility that other types of tin deposit may turn up, namely, vein and disseminated ores that have proved productive in other fields. The Manitoba region has not yet been prospected enough to eliminat the possibility of such occurrences. The disrict is assuredly worthy of further prospecting and investigation even though a commercial body of ore has not yet been established. A new tin occurrence is always a matter of interest and a new tin field must be examined on its own merits. There is not yet enough of a Precambrian tin tradition to guide us. Trained prospectors for tin are rare in Canada and it is one of the metals that is very elusive in the field and one that has not been carefully searched for."

Tin values are reported to have been obtained from assays of samples from Wintering Lake, near mile 185 on the Hudson Bay railway.

Reference: Tin Prospects in Manitoba, by J. S. De Lury, Canadian Mining Journal, August 30th, 1929.

CHAPTER VIII

METALLIC MINERALS (Cont'd)

RADIOACTIVE AND RARE EARTH MINERALS

RADIUM

The metal **radium** is found in a number of rare minerals, all of which contain also the rare metal **uranium.** The constant association of radium and uranium is explained by an unusual relation between these elements. Uranium is slowly decomposing with the formation of other elements, among which is radium. This takes place so slowly that in 5,000,000,000 years only one half the uranium has changed to radium. Half of the remainder changes in another period of the same length, and so on. Radium itself is an unstable element, and it is this property that gives it its usefulness in treatment of cancer and other diseases, and also its power of permanent luminosity. As it slowly disintegrates, radium gives off radiations that may be compared with light and heat rays. They differ from these, however, in their power of penetrating most substances. Metals, especially lead, are more or less "opaque" to radium rays. Radium bromide or

chloride is kept in lead tubes, not because the lead checks the decomposition of the radium,—no device of man has succeeded in checking, hastening, or retarding that process,—but to prevent the radiations from injuring anyone exposed to them. The radiations have the power of exciting chemical changes, and these changes may be made curative by the destruction of germs and diseased tissues; but they may also destroy healthy tissue. In the early days of experiment with radium, exposure to the radiations, for example by carrying a glass tube of radium bromide in a pocket, caused serious and even fatal ulcers. This power of radium to excite chemical change is sometimes shown by a peculiar discoloration of feldspar and other minerals near a mass of pitchblende or other radium-bearing mineral.

In addition to these rays of great penetrating power radium is constantly shooting off particles of the gas helium (see **Helium** p. 221) that have not the same power of penetrating solid substances, but are stopped by a sheet of paper. One of the products of the disintegration of radium is a very heavy gas called **radium emanation**. This gas is collected, compressed into needles or tubes and used in the treatment of cancer instead of the radium bromide or chloride. The gas loses its power in a few days. Radium emanation deposits a kind of lead, differing from common lead in having a somewhat lower atomic weight. This accounts for the presence of a little lead in all uranium minerals.

As the rate of disintegration of uranium is not influenced by circumstances, and since the rate has

been measured, it is possible to calculate the age of a uranium mineral, and hence of the rock in which it is found, by finding the ratio between the uranium and the lead in the mineral. Such calculations show that the pegmatite dikes in which radium-bearing minerals have been found in Canada are about 1000 to 1200 million years old.

The ratio of radium to uranium in uranium minerals is mostly constant. It is as 3.4 to 10,000,000. This works out to about 1 milligram (about 1/70 of a grain) of radium in 8 pounds of uranium oxide (U_3O_8). Thus when uranium minerals are discovered and the percentage of uranium oxide is found by analysis, the amount of radium can at once be calculated.

Radioactive minerals can be tested by their power of affecting a photographic plate or film even when the mineral is separated from the film by cardboard or paper. Since iron is not so easily penetrated by the rays, a key can be photographed by laying it on a sheet of paper placed over the plate and covering the whole with a thin sheet of cardboard on which the mineral is laid. Of course the whole operation must be carried out in such a way that the plate or film is protected from light. There is an instrument called **electroscope** that is commonly used for testing radioactive minerals. The radiations discharge the electric charge that keeps two thin leaves of gold or aluminum apart, and this causes the leaves to approach one another. Another handy instrument, the **spinthariscope,** takes advantage of the fact that when the radiations strike a surface covered with zinc sulphide they

cause a spark of light. These little instruments are handy, require no particular expertness, and are not expensive.

The proportion of radium in the mineral is so minute, and the expense of extracting it is so great, that the price of radium in the form of radium bromide or radium chloride is about a million dollars an ounce. It has been as high as three million dollars an ounce. Very small quantities, measured in milligrams, are powerful in the treatment of cancer and other diseases. The world's total production up to January, 1921, was estimated as about five ounces.

In addition to its use in the treatment of cancer and other malignant growths, radium is used in making luminous paint the luminosity of which continues indefinitely. It is also used to change the color of precious stones. Experiments show that radium increases the rate of growth of plants, and extremely minute amounts such as may be present in tailings from the concentration of radium ores may be useful as agricultural fertilizers.

The principal radium minerals are as follows:

Pitchblende or **Uraninite,** pitch-black, grayish, greenish, or brownish in color, very heavy and fairly hard; the fine powder is brownish black, olive-green or grayish; breaks with a round or somewhat uneven fracture; it contains uranium, lead, radium, and usually a number of other rare metals, also the rare gases helium and argon. There are many varieties of this mineral such as **cleveite, broeggerite, nivenite, etc. Pitchblende** is properly the pitchy mineral with no distinct crystallization and containing little or no thorium, cerium, etc. Uraninite is distinctly crystallized and carries considerable

proportions of thorium etc. It is found in pegmatite dikes, while pitchblende goes with silver-arsenic-cobalt ores.

Gummite is an alteration product of uraninite. It occurs in rounded or flat pieces looking much like gum. Its color is reddish yellow, orange yellow, or reddish brown.

Torbernite is a green mineral, often in thin transparent or translucent crystals, sometimes micaceous. It is a hydrated phosphate of uranium and copper.

Autunite is yellow, otherwise much like torbernite in appearance. It is a hydrated phosphate of uranium and calcium.

Euxenite and **Samarskite** are uranium-radium minerals somewhat like pitchblende in appearance but not so heavy.

Uran-ochre is a yellow incrustation formed by the weathering of uranium minerals.

Carnotite is a canary-yellow mineral, hitherto one of the chief sources of radium. In addition to uranium and radium, it contains the valuable metal vanadium. It occurs in large quantities in sandstone in the states of Colorado and Utah U.S.A. It has also been found as an incrustation on ilmenite.

Coracite has been described as a distinct mineral, but it is probably pitchblende that has been partly altered to gummite.

Ellsworthite occurs in roundish masses of a yellow or brown color. It contains about 15% of uranium, and in addition the rare elements niobium, tantalum, etc.

Hatchettolite is a mineral somewhat similar to ellsworthite, but lower in uranium.

Columbite and **cyrtolite** are rare minerals of this same family, usually carrying small proportions of uranium, but valuable for their tantalum, zirconium, and thorium content.

Allanite is a black or brown silicate of calcium, iron, aluminum, cerium, etc. It is sometimes radioactive, mostly on account of its thorium content.

THORIUM

The metal **thorium** is also radioactive, and minerals containing this metal show radio activity. Thorium resembles radium in slowly changing into helium and

lead, but at a much slower rate. An intermediate product is **mesothorium** valuable for the very penetrating radiations it gives off. It is used in making luminous paint, but the luminosity lasts only five or six years. All thorium minerals contain some uranium, and uranium minerals commonly carry some thorium. Since radium and mesothorium cannot be separated by chemical operations, it follows that radium products may contain more or less thorium, and mesothorium products, contain more or less radium.

Since the thorium minerals are of more importance as the source of products other than mesothorium they are described under another heading (See **Thorium p. 148**).

Uraninite and similar radium-bearing minerals are found in pegmatite dikes, particularly in those containing plenty of quartz and having the quartz and feldspar in separate large masses rather than in the well-mixed condition. But euxenite, samarskite, and the tantalum-niobium-thorium minerals are more likely to occur in graphic granite and other dikes in which feldspar and quartz are mixed rather than in separate large masses.

The radioactive minerals are not likely to be noticed on the surface, but yellow or orange stains may call attention to their presence. Another indication is the peculiar reddish color of the feldspar in the neighborhood of the radioactive minerals. The feldspar, quartz, or mica in which a mass of radioactive mineral is embedded shows cracks radiating from the mass. As magnetite and ilmenite are sometimes found in pegmatite dikes, they might be mistaken for

the black radium minerals, but the latter do not affect a compass, while magnetite does. Ilmenite is also sometimes strongly enough magnetic to affect a compass, but some specimens are very feebly magnetic.

Pitchblende has been found in silver-cobalt-arsenic veins, as in Joachimsthal, Bohemia, and in quartz veins associated with gold, as in Colorado. These quartz veins are in gneiss and mica schist. They were first worked for gold, but the gold values disappeared where the pitchblende came in. Such veins might be found in parts of Canada where pegmatite dikes are plentiful. These valuable minerals are sparsely scattered in a good many places, just as gold is; and just as in the case the gold, the exceptional place must be sought where the concentration of the valuable minerals is unusually great. The typical pegmatite dikes may not supply this exceptional concentration. Vein-dikes that are mostly quartz, or those that contain large proportions of calcite, may be more favorable.

Radioactive Waters

Radioactive waters owe the property to radium, radium emanation, or both, picked up by the water in its passage through soil and rocks. Nearly all rocks contain a little radium, there being more in igneous than in sedimentary rocks. As soil is composed largely of the débris of rocks, it also carries a little radium. If the water has only radium emanation dissolved in it, its radioactivity disappears in a few days. If, on the other hand, its activity is due to dissolved radium, the activity is permanent. Most waters show a little temporary activity.

The curative powers of some waters may be due to the radioactive substances dissolved in them. The gases from some mineral springs contain helium, one product of the disintegration of radium. The waters of these springs are likely to be radioactive, as is the case with the waters of the famous hot springs at Bath, England. The curative properties of radioactive waters have been established by experimenting with artificially charged water. The chief curative agent is radium emanation.

URANIUM

Uranium minerals are found mostly in varieties of granite, particularly in pegmatite dikes, quartz porphyry, and other varieties of granite formed in the final stages of the cooling of granite magma. These minerals are also found in vein-like structures associated with granite and in the wall-rocks of the granite and other dikes. (See **Radium** p. 137).

Uranium oxide is used to give a yellow colour to glass. Uranium glass has the peculiar property, **fluorescence.**

Radioactive minerals have not been discovered in Manitoba, but the large extent of country in which pegmatitic is found makes it probable that these minerals will be found as prospecting becomes more widespread and detailed.

METALS OF THE RARE EARTHS

Under this heading are described a number of rare minerals carrying metals the oxides of which are

earthy substances. Either the metals or their oxides have been made useful. The minerals carrying them occur in granite and similar rocks, so that there are fair chances of finding workable deposits in Canada.

BERYLLIUM

Beryllium is a very light metal found in a number of rather rare minerals, the most abundant of which is **beryl,** a silicate of beryllium and aluminum. Precious varieties of this mineral have long been known as emerald and aquamarine. **Chrysoberyl,** mostly green in color, an oxide of beryllium and aluminum; and **phenacite,** usually yellow in color, a silicate of beryllium, may also be of importance in the manufacture of the metal. When not distinctly colored these minerals may not attract attention. Beryl crystals are six sided and look a good deal like quartz crystals, but some greenish shade may be noticeable in the beryl crystals.

The beryllium minerals are found in granite, particularly in the coarsely crystallized variety called pegmatite.

As beryl sells for $60 a ton and upwards, the discovery of an unusually large and concentrated deposit would be very important. Beryl as mined contains only from 3 to 3.5 per cent of the metal beryllium. Chrysoberyl contains theoretically over 7 per cent and phenacite over 16 per cent. The discovery of large masses of chrysoberyl or phenacite would be still more important.

The metal is extracted by a long and difficult process, the last part of which involves decomposition at a very high temperature by an electrical current.

Pure beryllium is a very hard and brittle metal. So far there has been no success in the attempts to roll or draw it. Its very low specific gravity suggests its use as an alloy with other light metals such as aluminum to increase their hardness. The addition of 2 to 2.5 per cent of beryllium to copper or nickel produces alloys with the properties of bronze, but capable of developing great hardness and toughness by heat treatment. Beryllium increases the electrical conductivity of copper castings. The present high cost of beryllium will prevent its use for most of these purposes, but the discovery of more plentiful raw material for its manufacture and improvements in the extraction process may soon bring its price within range.

While none of the beryllium minerals have so far been found in Manitoba in sufficient quantities to be economically important, beryl in particular occurs so frequently that the prospect of discovering a workable deposit seems fair. The acid pegmatites, in which beryllium minerals occur, are very plentiful in the Precambrian regions of the Province.

Beryl occurs frequently in the pegmatite dikes of the Oiseau River district. It has been noticed in the lithium deposits of the Bernic Lake and Cat Lake areas. The mineral has been found only sparingly in these areas, but near Shatford Lake larger quantities have been discovered, and further prospecting may locate a commercial deposit of the mineral. A ship-

ment of 500 pounds from property owned by the Jack Nutt Mines, Ltd., is said to have assayed 4 per cent of beryllium. This is higher than the beryllium content of beryl as usually mined.

CERIUM

This metal is present in a number of rare minerals, usually with thorium and sometimes with uranium (See **Thorium** p. 142 and **Uranium** p. 144). **Monazite,** a phosphate of cerium, thorium, etc., is the principal source of cerium products. It is a red, brown or yellowish mineral found in granite and gneiss in scattered grains. It is hard enough to stand a good deal of wear, and heavy enough to get to the bottom of a body of sand resulting from the breaking down of rock. The source of monazite is the sands in certain parts of North Carolina, U.S.A., which are concentrated by washing. In a glaciated country like Canada the chances of finding such accumulations of monazite are not good, but it should be watched for in panning. Its red or yellow colour attracts attention when it shows in panning for gold. Allanite or cerium epidote is found in pegmatite dikes and other granite structures. Although not so far observed in Manitoba, its frequent occurrence in eastern Canada suggests that it may be found in sufficient concentration to be an economic source of cerium products.

Cerium is used in making **ferro-cerium,** the substance that sparks and lights a gas jet when it is rubbed against steel in the well known instruments and toys. Cerium oxide is used as a constituent of gas mantles, etc.

TANTALUM

Tantalum is a rare metal found in a number of rare minerals forming related groups including the **columbite-tantalite** and the **samarskite groups.** Most of them when finely powdered are brownish.

Columbite and **tantalite** are minerals that grade into each other according to the percentages of columbic (niobic) and tantalic acids. They may carry important proportions of cerium.

The metal tantalum sells for $6 an ounce. It has been used for making the filaments of electric light bulbs.

Tantalite has been observed in small quantities associated with lithium minerals on the property of the Silver Leaf Mining Syndicate about 12 miles east of Point du Bois on the Winnipeg River.

THORIUM

Thorium is a rare metal that is a constituent of a number of minerals including monazite (See **Cerium** p. 147), thorite, a silicate, and several others. Thorite is usually dull black, and brown when finely powdered. It is sometimes orange-yellow and is then called **orangeite.** (See **Radioactive Minerals** p. 142). The specific gravity of these varieties ranges from 4.6. to 5.4. They are accordingly fairly heavy minerals. and are hard enough to stand wear. They may therefore sometimes turn up in panning sand or gravel.

Thoria, as the oxide of thorium is called, is used in making gas mantles. It has the property of giving off an intense white light when heated. (See also **Radio-**

active Minerals, p. 141). Minerals containing not less than 6% of thoria sell for $120 a ton.

Thorium minerals have not been found in commercial quantities in Manitoba.

The uranium minerals described under **Radium** p. 142 contain more or less thorium.

ZIRCONIUM

Zirconium is a rare metal found in a number of minerals, some of which have already been mentioned (See **Radioactive Minerals** p. 140) **Cerium** p. 147) and **Thorium** p. 148). The principal sources of zirconium products are monazite and zircon. **Zircon** is a silicate of zirconium. It is reddish brown, brownish yellow, pale yellow, yellowish green, gray or white in color. It is harder than quartz, and, being fairly heavy, it is apt to collect in the sand and gravel formed by the disintegration of rocks in which it is found. It occurs in pegmatite dikes and other syenite, nepheline-syenite, and granite structures, and sometimes in crystalline limestone, schists, and gneiss. Concentrates containing 95 per cent of zircon sell for $60 a ton. **Zirconia**, the oxide of zirconium, is used in the manufacture of incandescent gas mantles. Zirconia, like thoria, has the property of giving off an intense white light when heated. There is a refractory named **zirkite** made from zirconia. It sells for $50 to $100 a ton.

The principal zirconium mineral, zircon, has been observed in several localities as a constituent of granite. For example, on an island north of Soulier Point, near Norway House, Little Playgreen Lake, Nelson

River, is a granite rock that shows zircon crystals of microscopic size. Zircon crystals have been observed in similar rocks on a small island one quarter of a mile west of Soulier Point, and on another about a mile north of Norway House. Zircon is the principal heavy mineral in the Winnipeg sandstone. No zircon deposits of economic importance have been discovered in the province.

CHAPTER IX

NON-METALLIC MINERALS

CORUNDUM, GARNET, SILICA, CRYOLITE, FELDSPAR FLUORSPAR, ANDALUSITE

CORUNDUM

This mineral is crystallized oxide of aluminum. The crystals when well-formed can be seen to be six-sided prisms. Next to diamond, corundum is the hardest of minerals. In an impure form it has long been used as emery for abrasive purposes. The pure corundum is superior to emery for these uses.

Uses. The principal use is as an abrasive, that is, for grinding and polishing. For these purposes it is made into wheels, whetstones, abrasive paper and cloth; but the loose grain or powder is used for polishing, etc. **Carborundum,** a name having a flattering resemblance to **corundum,** is a compound of carbon and silicon made in electric furnaces (omitting details) by fusing the cheap materials coke and silica sand or some other form of silica. Artificial corundum is another competitor, made by the long-continued action of electrical heat on bauxite, which is oxide of aluminum combined with water. By putting it through a chemical process and heating the product, pure oxide

of aluminum is obtained. It has no cutting power because it is not crystallized. When heated in an electrical furnace, it crystallizes, and the product is entitled to the name corundum. Both the natural and the artificial are crystallized oxide of aluminum. Artificial corundum is on the market under the name **alundum.**

There is no reported occurrence of corundum in Manitoba.

GARNET

The garnet family includes a number of minerals similar in composition and alike in their crystal forms. They are all silicates, and most of them have also the oxide of aluminum as part of their composition. The common commercial garnet, **almandite,** is silicate of aluminum and iron. The crystals of garnet are in the cubic system, and this gives them a tendency to take on forms that appear in the rock as nodules, and as garnet weathers more slowly than the other minerals forming the rocks in which they are found, these nodules or grains are apt to stand out from the surface. The color of the common garnet is red or brown, but there are black, green, yellow, and white varieties. The hardness varies from 6.5 to 7.5, using the scale in which the hardness of quartz is 7.

Garnets occur in a great variety of rocks, but garnet-gneiss and garnet-schists are the principal sources of commercial garnet. These are plentiful in Manitoba, but the requirements of a commercial deposit are so exacting that very few are found to fulfil them. The crystals must not be too small, not less than pea size. They must break so as to give grains with

good cutting edges. The hardness must be the maximum for garnets. Pink or red color is preferred by the trade, although the best qualities may be found in garnets of other colors. The amount of garnet in the rock should not be less than 10%.

Apart from their use as jewels (See **Precious** and **Semi-precious Stones**, p. 199) the greater part of the garnet produced is used in the manufacture of garnet-coated papers and cloths, a little being used in the loose condition for polishing, for sand blast, for finishing plate glass, and similar purposes. Garnet-coated paper and cloth are used extensively in wood-working and leather industries.

Garnet concentrates sell for about $85 a ton. The concentration is effected by the usual gravitation methods, which are suitable for garnet as it is heavier than most of the minerals with which it is found. Magnetic separation may be required to remove magnetite, etc. Hornblende, which is fairly high in iron, can also be removed by magnetic separation.

The extensive and numerous areas of schists and gneiss in Manitoba, due to contact metamorphosis, no doubt include many examples of garnet-bearing rocks in addition to the few that are already known. When the demands of the abrasives industry justify a search in Manitoba for garnet deposits of the right quality and favorably situated, attention will be given to the Precambrian country in the southeast part of the province, and to those parts farther north that are near the railway lines.

In the report of the Geological Survey of Canada there is frequent mention of garnet-bearing gneiss

and schist. For example in the report for 1878-79 at page 27 C mica schist studded with garnets is referred to, and at page 36 C hornblende schist full of dull garnets is mentioned.

Winnipeg River

In township 16, range 16, on the south side of the river east of Lamprey Falls, garnet rock occurs in sections 21, 24, 28, and 29. The garnets are red, up to ½ inch in diameter, the average less than ¼ inch, and are cemented together by a clay-like material. In places the garnets form about three quarters of the rock. Two such deposits noted are 6 feet wide and have been exposed for a length of 200 and 250 feet. A little quartz and pyrite is mixed with the garnet.

Wekusko Lake

East of the outlet of Anderson Lake in the Wekusko Lake area of Northern Manitoba is a ridge of schist part of which is a garnet-bearing mica schist in which the garnets are up to 2½ inches in diameter. They form the greater part of the rock and are of good quality. Garnets are abundant in gneiss on the east shore at the north end of Crowduck bay.

Long Lake

On the south side of Long Lake, an expansion of the Manigotagan River, is an area of slate and gneiss with small red garnets in abundance.

Rice Lake and Beresford Lake

Around Rice Lake and Beresford Lake are slates more or less changed to schists and carrying an abundance of small red garnets.

References: The Non-Metallic Mineral Resources of Manitoba, by R. C. Wallace and L. Greer, Industrial Development Board of Manitoba, Winnipeg, 1927.

Geological Survey of Canada, Reports, 1917, Part D, p. 12; 1923, Part B, p. 92; 1924, Part B, pp. 63 and 100.

SILICA

Silica is the material of which quartz is composed. It is the oxide of an element named **silicon,** present in pig iron and steel. In the blast furnace the silicon has been reduced from the silica mixed with the iron ore. Silicon is also a component of **ferrosilicon.** In nature, it is always the oxide, silica, or some compound of it, a **silicate,** that occurs. Quartz is the common crystallized form of silica. There are other forms such as chalcedony, flint, etc., that are not obviously crystalline. In addition to silica, opal contains a little water. For information about some varieties of silica, see **Precious** and **Semi-precious Stones** p. 200.

The varieties of silica of importance economically are vein or dike quartz, flint, sand, sandstone, quartzite, diatomite or tripolite, rottenstone, and tripoli.

Quartz

As vein material and a constituent of various rocks, quartz makes up about 12% of the earth's solid crust. When pure it is colorless and usually opaque in considerable masses but translucent or transparent in small grains. It is often colored by impurities.

While quartz is a constituent of acid rocks such as granite, mica schist, and granite-gneiss, it cannot be

economically concentrated from these rocks. A common source of quartz is pegmatite dikes in which large masses of the mineral are found unmixed with feldspar or mica. Quartz is sometimes quarried along with feldspar. Another source is the tailings from gold mills. In smelting operations, a low grade siliceous ore of copper is sometimes mixed with ores having a gangue high in lime and other bases. The quartz helps to form a fusible slag.

Flint

Flint is a kind of silica not obviously crystalline, although the miscroscope shows that it is made up of very small crystals. It is found in some countries as nodules in chalk and limestone. Impure flint is often called **chert.**

Sand

When granite and other rocks containing quartz disintegrate, the grains of quartz, being harder and less liable to decomposition than other minerals, endure longer during the process of weathering and washing down into hollows. It thus comes about that beds of sand are composed largely of grains of quartz. The name **silica sand** is used for beds that are free or nearly free from other minerals. Such sand has the advantage of being already in a state of fine division, so that the expense of crushing is saved.

Sandstone

This is a rock composed of grains of sand more or less water-worn, and cemented together by silica, calcite, limonite, or sometimes by a little clay that has been mixed with the bed of sand from which the

stone has been formed. The grains of quartz vary in size in different sandstones, and the cementing is more or less effective. The sand may have been white silica sand, or it may have been more or less mixed with other minerals. The cementing material may be white or may have some color. These varying circumstances have influenced the appearance, texture, and composition of the sandstone.

Quartzite

Quartzite is a rock formed from sandstone by the influence of heat, pressure and the action of materials from the hot masses of rock matter that have invaded the region. The grains of quartz are more completely cemented by the filling up of inter-spaces with silica, the other minerals mixed with the quartz may have been re-combined and crystallized so as to form mica, etc., and these changes may have gone so far that nothing of the original granular structure of the sandstone is visible to the unaided eye. Quartzite sometimes looks very much like vein quartz.

Diatomite

Also called **infusorial earth, diatomaceous earth, kieselguhr**, and **tripolite**. It is a deposit made up of the silica skeletons of minute plants called **diatoms,** that grow in both fresh and salt water. The deposition is going on constantly in favorable places, as in quiet shallow lakes. Accumulations of past ages are sometimes found as a soft rock, as in the immense deposit in California. More recent deposits are occasionally found in old lake bottoms where some change in levels has caused the water to drain off. The mud at the

bottoms of some existing lakes consists of this material.

Diatomite is not likely to be found in the consolidated state in a country that has been severely glaciated; but deposits formed since the Great Ice Age are possible. To be of economic importance a diatomite deposit must be large, easily accessible, and free from clay and other impurities.

Rottenstone and Tripoli

These are siliceous materials left by the weathering of siliceous limestone, etc. Rottenstone is a soft, porous, rusty rock, used for polishing furniture, celluloid, and plate glass. Tripoli looks a good deal like diatomite, but the microscope fails to show the diatom structure. Glaciation has made it unlikely that such soft surface materials, requiring ages for their accumulation, will be found in most parts of Canada.

INDUSTRIAL USES OF SILICA

Whatever its source or natural form, pure silica is the same substance. Differences in the natural materials, such as vein quartz, sandstone, quartzite, and sand are due to their state of division, and to other substances mixed with the silica. Diatomite comes near opal in its composition, and is a little softer than crystallized quartz. It is also very porous. When silica is required for fluxing in smelting operations, for example, the requirements are that it shall be cheap, as nearly pure as possible, and of a suitable size for furnace operations. These conditions being fulfilled, the origin of the silica, whether vein quartz, sandstone, or quartzite, is not important. But if the silica

is to be used in a finer state of division, the shape and size of the grains must be considered. Natural sand is not suitable material for making silica bricks, even if its analysis shows that it has the same composition as ground quartzite that makes good bricks.

In the industries, silica is used as **lump silica, silica sand,** and **ground silica.** These are commercial terms indicating certain sizes of pieces or grains, lump silica being the largest and ground silica the smallest.

Uses of Lump Silica

This product is obtained as vein quartz, sandstone, or quartzite. It may be used as quarried, but for some purposes it is crushed and sized. In any case it commands a low price only.

Ferrosilicon is made in an electric furnace (1) by the reduction of silica and iron ore with carbon or (2) by the reduction of silica, the iron being added as turnings. The silica may be high grade quartzite or may be in the form of a highly siliceous iron ore. The most objectionable impurities are phosphorus and arsenic which lead to the generation of very poisonous gases when stored ferrosilicon is acted on by the moisture of the air. Lime and magnesia should not exceed 0.20% each. The quartzite should analyze 97½% of silica or more. Ferrosilicon is used in the manufacture of steel.

Use as a Flux. In the smelting of copper ores that have a basic gangue, silica may be required as a flux. Another copper ore with a silica gangue is the most economical source of silica. The silica is required to form a fusible slag with the oxide of iron and other basic materials in the ores.

Other uses. In the manufacture of phosphorus from bone ash and apatite, silica is used to flux off the lime. Very pure silica from feldspar quarries has been used for this purpose.

Blocks of vein quartz and quartzite are used in certain chemical industries where acid gases are passed through towers to dissolve in water trickling over the quartz.

On account of their great hardness pebbles of flint or quartzite are used in rotating mills for fine grinding of ores, etc. The linings of these mills are also commonly made of the same materials.

Uses of Silica Sand

The sand may be either natural shore sand, or ground sandstone or quartzite.

Silica Brick is essentially grains of silica cemented by a little lime. The bricks will stand a very high temperature, and are used for lining metallurgical and other furnaces. The silica used is quartzite crushed to a small size. **Gannister** is a siliceous rock containing enough highly refractory clay to act as a bond. (**Refractory** materials are those that will stand a high temperature without melting and also resist the chemical attack of the materials charged into the furnace.) Quartzite is preferable to vein quartz, sand or sandstone, and it must be very high in silica, say 98% or more.

Glass Sand. Ordinary glass requires 50 to 75% of silica for its manufacture. Pure white silica sand is commonly used. It must be free from iron, alumina, magnesia, lime, and alkalies. The absence of lime and

alkalies (potash and soda) is desirable, although both are used as part of the charge. If they are present in the sand, they have to be allowed for, and that is troublesome. Crushed sandstone, quartzite, and vein quartz may be used, but the natural glass sand can be got so cheap that it rarely pays to use the other materials.

Manufacture of Carborundum. This abrasive is a compound of carbon and silicon. Silica is the oxide of silicon, and silica sand is one of the raw materials used in the manufacture of carborundum. It is charged into electrical furnaces with coke, sawdust, and salt. The sand must be at least 99.25% silica, and must be free from lime, phosphorus, and magnesia.

Steel Foundry Sand. Sand for the moulds in steel foundries is carefully selected for refractoriness, bonding power, and permeability to gases.

Silica Sand for Furnace Linings. Natural sand or crushed quartzite is used to line Bessemer converters, for the hearths of reverberatory furnaces, for matte smelting, and to line electric furnaces for melting scrap iron. The material should be 95% silica or over, and should be of even grain.

Fused Silica Ware. The high fusion point of pure silica made it impossible to construct ware of this material until the electric furnace came into use. In these the silica is packed around a perforated carbon tube through which air can be forced to blow the softened silica out until it fits the mould. Fused silica ware is highly refractory, very strong, and can be heated and cooled suddenly without cracking. Ma-

terial of the quality of glass sand is required for its manufacture.

Minor Uses of Silica Sand. There are a number of smaller uses, such as the manufacture of sand paper and other abrasive and polishing apparatus. For these purposes crushed quartzite or vein quartz has a better grain than crushed sandstone or natural sand.

Uses of Powdered Silica

Under this head are included all silica materials ground to a fine powder, too small to be classed as sand. It is made from flint, vein quartz, quartzite, or sandstone.

Powdered Silica in Pottery. It is used to the amount of 35% in the bodies and also in the glaze of table ware, sanitary ware, floor tiles, etc. The iron content should not exceed 0.32%. Ground silica is used in metal enamelling.

Powdered Silica in Paint. The finest powdered silica is now a standard material in paint. It must be free from color. It increases the durability of the paint.

Sodium Silicate. This material, also called **water glass** or **soluble glass,** contains about 79% silica. It is made by fusing powdered quartz with sodium carbonate or sodium sulphate. Another way is to heat silica under pressure with a solution of caustic soda. For this method, diatomite is preferred, as it dissolves more easily than other forms of silica.

Other Uses. Powdered silica is used in the manufacture of asbestos shingles, as a filler and scourer in hand soaps, in dental work, and for a number of other small uses.

Uses of Diatomite

The three largest uses are as an abrasive, as a heat insulator, and as a filter and decoloriser. As an abrasive it owes its usefulness to its hardness and to the sharpness of the grains. Its insulating power depends on its porosity, which also doubtless aids its usefulness as a filter. Other uses are the manufacture of sodium silicate, as a filler for rubber, sealing wax, phonograph records, and other manufactures requiring a cheap inert material. A new use of growing importance is to mix with concrete. It fills the spaces and makes a uniform mixture with less water.

SILICA IN MANITOBA

Sand

Sand of recent formation is found in many parts of the province, but none so far as known is pure enough for glass-making. On the shores of Lake Winnipeg, the sandstone has washed down and formed beds of beach sand in many places. The purest of this beach sand is on Black Island, Punk Island, and at Grindstone Point. Black Island sand is used for lining the bottoms of furnaces. When washed it is suitable for glass manufacture.

Glacial sands are numerous, but they are usually high in lime. A deposit at Beauséjour was at one time used in the manufacture of cheap grades of green, bottle glass, and also sand-lime brick.

Sandstone

Sandstone of Cretaceous age ("Dakota") is exposed on the banks of the Red Deer, Armit, Swan and

Carrot rivers. It is also to be seen at Kettle Hill on Swan Lake. The sandstone is very soft and sometimes quite unconsolidated. Being far from transportation it is not at present easily available. The Swan River sandstone is over 96 per cent silica and of even, angular grain.

Sandstone of Ordovician age, called **Winnipeg sandstone,** is considered to be the most promising source of high-grade silica in the province. It outcrops on a number of islands in Lake Winnipeg, particularly on Elk, Black, Deer, and Punk islands; also on Grindstone Point and along the shore of Washow Bay west of Anderson Point. It is also seen along the shores of Simonhouse Lake south of the Cranberry Lakes on Grass River. The sandstone is at most only loosely consolidated and is often unconsolidated, so that it can be easily shovelled. Much of it is pure white, but in places it is stained red or chocolate with iron oxide and clay. It varies in thickness from 100 feet to a few inches.

Quartzite

Quartzite is known to occur in many places in the Precambrian parts of the province, particularly in Northern Manitoba. Some of the quartzite in the Oiseau River area may be pure enough for the finer uses.

Vein Quartz

In the gold areas there are many examples of quartz veins that may be drawn upon as sources of silica. In the same regions there are deposits of copper ore (as at Flin Flon) for the smelting of which silica may be required as a flux. Quartz veins with too low

a gold content for gold mining may be used in such operations, the gold being recovered in refining the copper.

The quartz in pegmatite dikes is sometimes in separate masses large enough to be taken out by themselves when feldspar is being quarried. Pegmatite dikes are numerous in the region east of Lake Winnipeg and in parts of Northern Manitoba. They are particularly plentiful in Southeastern Manitoba. (See **Feldspar** p. 166).

References: Silica in Canada, by L. Heber Cole, Mines Branch, Ottawa, publication No. 686, Part II, p. 2.

Geological Survey of Canada, Summary Report, 1924, Part B, p. 99.

The Non-Metallic Mineral Resources of Manitoba, by R. C. Wallace and L. Greer, Industrial Development Board of Manitoba, 1927.

CRYOLITE

While a cryolite deposit has not so far been discovered in Manitoba, the mineral is so important in the manufacture of aluminum and various enamels, etc., that some mention should be made of it, especially as the geological conditions of large parts of Manitoba are favorable to its occurrence. It is a mineral of rather unusual composition, fluoride of sodium and aluminum. It owes its value to its easy fusibility and to its power of causing the fusion of more refractory substances. It is a white mineral, although sometimes colored by impurities. It looks somewhat like quartz

but is a good deal softer. There is only one workable deposit known in the world, at Ivigtut in Greenland, where it is found as a vein or dike in gneiss. Small quantities have been found in other places in pegmatite dikes, and the Greenland cryolite may be looked upon as a freak pegmatite dike in which everything was left out but the cryolite. Considering the abundance of pegmatite dikes in the granite and gneiss regions of Manitoba, the chances should be good for finding the second cryolite vein to help supply the world's demand. Prospectors should acquaint themselves with the mineral, so as to recognize it, if they should happen upon it.

The discovery of a workable deposit of cryolite in Manitoba would be of major importance.

FELDSPAR

This name is applied to a family of minerals which are alike in being all composed in part of silica and aluminum oxide. They are all **silicates of aluminum** with either **potash, soda,** or **lime.** So there are **potash feldspars, soda feldspars,** and **lime feldspars.** Most feldspars are of an intermediate composition. For example, the commonest commercial feldspar is a potash feldspar called **microcline,** which generally has from 2 to 4% of soda in place of part of the potash. Another common potash feldspar is **orthoclase,** the most plentiful feldspar of ordinary granite. **Albite** is a soda feldspar, common in granite and syenite. **Labradorite** is a lime feldspar.

In the manufacture of pottery and similar industries, feldspar is used both as an ingredient of the

clay or other body and as a glaze for the finished products. For the latter purpose especially, the fusion temperature must be as low as possible, and this property is best in a potash feldspar containing a few per cent of soda. Feldspar of this composition has also the property of not shrinking too much on cooling.

Commercial feldspar is found in a variety of granite called **pegmatite,** characterized by the large size and irregular distribution of the crystals of feldspar, quartz, and mica. This rock is largely in the form of dikes, that is, masses that have a great length in proportion to their width and that have broken their way through other rocks from below so as to form a rock mass approaching the vertical in position. Pegmatite dikes show a great variety in size and composition, and it is only the exceptional one that is suitable as a source of commercial feldspar. The feldspar must be in masses large enough and pure enough to permit it to be quarried without much hand sorting. Certain dark colored minerals such as tourmaline and hornblende must be absent, and very little quartz is permissible for the best grade feldspar. The market price is so small, $5 to $8 a ton, that no great length of haul to railway or water transportation can be borne. These requirements rule out the great majority of the thousands of pegmatite dikes known in Manitoba.

Uses. The greater part of the feldspar is used in the manufacture of pottery, partly to mix with clay and partly to glaze the dishes. The amount of feldspar used in the body of the dish may be as much as

36%. The glaze is made of feldspar mixed with clay, etc. in such proportions as to melt at a lower temperature than the softening point of the dish. Feldspar is the chief ingredient in enamels for iron ware. It is also used in making opalescent glass, and other special kinds of glass. For making artificial teeth feldspar of especially high grade is used, and the requirements for "dental spar" are so exacting that the price is about four times that of ordinary No. 1 "spar." Other uses are in abrasive soaps, as a binder in making corundum and other wheels, for floor and wall tiles, and in paints. Crude feldspar of lower grades is used for stucco-dash and roofing, and for chicken grit. Much experimenting has been done to find some profitable method of extracting the potash from feldspar, but so far without commercial success. To render the potash soluble for plant food, C. W. Drury fuses feldspar with iron ore to form a slag in which the potash is so easily soluble that it should serve the purpose of a plant food. More elaborate proposed methods separate the three constituents, potash, alumina (oxide of aluminum), and silica, all of which are useful.

Pegmatite dikes are plentiful in a considerable proportion of the areas in Manitoba that have been geologically mapped. They are especially numerous in Southeastern Manitoba. West of Point du Bois and east of Lamprey Falls occur large dikes some of which carry as much as 95 per cent of feldspar. In many of the dikes the crystallization is coarse and the feldspar could be easily separated from the quartz. Feldspar crystals up to 2 feet long occur in some of the pegmatite dikes along the east shore of the Win-

nipeg River just west of the Ontario boundary. These dikes may be looked upon as reserves of feldspar to be drawn upon when transportation facilities warrant it.

FLUORSPAR

Also called **Fluorite.** Fluorspar is commonly white, but often shows shades of green, blue, and purple. It is harder than calcite, being of standard hardness 4, while that of calcite is 3. It is found in veins, and is fairly common as a constituent of metal ore veins. It is only exceptionally that the vein-filling consists of fluorspar exclusively or almost so. For commercial purposes a fluorspar vein must have very little of the sulphur minerals such as pyrite and barite, and the proportion of silica must be low. The composition of fluorspar is **calcium fluoride. Calcium** is a metal of which lime is the oxide. **Fluorine** is a gas closely related to chlorine.

Uses. Fluorspar is used largely as a flux in the manufacture of open hearth steel. For iron- and steel-making fluorspar must be at least 80% calcium fluoride and must be free from sulphides, sulphates, and phosphates. For the "acid" steel process the requirements are still more rigid, namely, not less than 98% calcium fluoride, not more than 1% silica and freedom from sulphur and phosphorus.

Fluorspar is used in the manufacture of glass and enamels, and as a bond in making emery wheels and carbon electrodes. It is the raw material for the manufacture of hydrofluoric acid used to etch glass and for other purposes. Fluorspar is the starting point in

the manufacture of important materials used with cryolite in the reduction of aluminum. Very perfect colourless crystals are in demand as "optical spar" for the manufacture of certain optical instruments. For such exceptional crystals a high price is paid.

While no commercial fluorspar deposits have been found in Manitoba, the extent of country in which such vein-filling is possible is very great, and the mineral should be watched for, particularly in those areas where lead and zinc sulphides occur.

ANDALUSITE ETC.

This is one of a group of silicates of aluminum including also **sillimanite**, and **cyanite**, of late years assuming importance in the manufacture of refractories, particularly spark plugs and refractory bricks. The minerals are found in metamorphic rocks such as gneiss, schist, and quartzite, usually near contacts with intrusive igneous rocks. Their occurrence in masses sufficiently large and pure for mining is very rare. They are hard minerals, and a little heavier than quartz. Andalusite is white, reddish, grayish or green. Sillimanite is brownish, gray or pale green. Cyanite is usually blue but is sometimes white. The cleavage of the three minerals is perfect.

Cyanite occurs in mica-schist on Anderson Lake in the Wekusko Lake area, and sillimanite is reported from a number of localities as a constituent of gneiss, but these occurrences are not of commercial importance.

CHAPTER X

NON-METALLICS (Cont'd)

IRON PYRITES, GRAPHITE, MICA, PHOSPHATE, TALC, ASBESTOS

IRON PYRITES

Introduction. It is also called **pyrites** and **pyrite.** It is a compound of iron and sulphur, valuable for its sulphur, of which the pure mineral contains 53.3 per cent. It burns easily in a furnace called "**pyrites burners,**" where the sulphur is oxidised to sulphur dioxide, a gas used in the manufacture of sulphuric acid, and many other chemicals. This gas is also used to make **bisulphite of lime** in the sulphite process for paper-making from wood. The residue of oxide of iron, sometimes called **blue billy,** has been used as iron ore, but unless the sulphur is completely burned away, its presence lowers the quality of the iron and steel.

Pyrite is a yellow mineral, the shade varying from golden-yellow to yellowish gray. It is harder than steel, with which it easily strikes fire. Its specific gravity is 4.95 to 5.1. The fine powder is black. Well formed crystals of pyrite often occur, cubes,

octahedrons, and cubes with edges bevelled in a rather complicated way (pyritohedrons) being the commonest forms. When the mineral is fine-grained, as it usually is, these crystal forms are not obvious.

As the prices paid for pyrite are small, from $4 to $6 a ton f.o.b. at a railway, the requirements for an ore body commercially workable are rather exacting. It must be fairly pure pyrite. If it assays 50% sulphur, this requirement is well met. Ore carrying 40% sulphur is marketable, if other conditions are satisfactory. Pyrite that is obviously mixed with a large proportion of rock is of no value as pyrite. The absence of arsenic and antimony is desirable, as these elements hurt the quality of sulphuric acid made from pyrite containing them. Selenium is also objectionable for the same reason. Lead and copper must not be present in more than small proportions, as they make the ore more easily fusible and so introduce difficulties in burning. Lead, lime, and some other substances hold back a certain proportion of the sulphur, and so decrease the value of the ore. Pyrites carrying more than 8 per cent of copper cannot be profitably used in making sulphuric acid, but it could be smelted for copper. Another condition is that the ore body must be large enough to warrant development and to maintain a steady supply for a number of years. The low price of the product makes it imperative that the deposit should be near transportation. The discovery of beds of sulphur in Louisiana and Texas put large supplies of nearly pure sulphur on the market at a price with which Canadian pyrites could not easily compete. But it is only a matter

of time until the sulphur deposits are exhausted or more expensive to mine. That this time is not far distant is shown by the tendency to higher prices for sulphur. It is said that certain manufacturers of sulphuric acid are already looking into Canadian pyrite deposits.

Pyrite weathers rather easily, forming one product that is obvious, iron rust or **limonite,** and another, **sulphuric acid,** that washes away. The limonite or **gossan** capping is a guide to pyrite deposits, but it should not be forgotten that a number of other iron minerals, such as pyrrhotite, also weather so as to form gossan. The capping is sometimes hematite, a reddish material. These signs of a pyrite deposit are easily seen when on a hillside where not covered by soil, but as pyrite weathers faster than the rocks in which it is found, the deposit may underlie a hollow. A very rusty soil (brown or red) that passes into soft limonite or hematite with depth should be trenched to solid rock.

Oiseau River Area

The **Rathall** deposit is about two thirds of a mile south of the west end of Oiseau Lake. It consists of schisted quartzite with masses of almost pure pyrite. The sulphide zone, so far as exposed, is 5 feet wide. There are several other gossan-covered zones south of Oiseau Lake. Similar gossan zones occur in section 16, range 16, township 16, the fresh minerals being pyrite, pyrrhotite, and mispickel.

Northern Manitoba

In the Flin Flon area and eastward pyrite is the most abundant sulphide in the copper-zinc deposits.

In the process of separating the copper and zinc sulphides from the ore, the pyrite may be concentrated sufficiently to serve as a source of sulphur. In a fine state of division it can be burned as powdered fuel in special furnaces. There are also bodies of sulphides barren of valuable metals, like those between Copper Lake and Brunne Lake. These may be utilized when the demand for such a source of sulphur justifies.

In the Cold Lake district there are large bodies of barren pyrrhotite that may come in at some time in the future as sources of sulphur.

GRAPHITE

Introduction. Graphite is a crystalline variety of carbon. Diamond is another crystalline variety. Non-crystalline or amorphous carbon is known as coal, coke, charcoal, lamp-black, etc. Amorphous carbon such as coke can be made to crystallize when heated by electricity. It then becomes graphite. While graphite burns with the formation of the same product, carbon dioxide, as is yielded by the combustion of coal, coke, and charcoal, it burns very slowly, so that it can be used in the manufacture of graphite crucibles, arc light electrodes, etc. Its softness makes it useful in the manufacture of lead pencils. As it is a good conductor of electricity, it is used to give a conducting surface to objects on which metal is to be deposited by electric current. This property also explains in part its usefulness for electrodes. Its softness and its resistance to oxidation make it a suitable substance for foundry facings.

Varieties of Graphite. Three varieties are recognized commercially, (1) Crystalline, (2) Flake, and (3) Amorphous. **Crystalline graphite** is in masses of crystals not definitely in flakes. It is found in small veins or in bunches and pockets along the intrusive contacts of pegmatite dikes with crystalline limestone, schists, etc. It is the purest form of graphite and can usually be marketed after hand-picking. The veins are so small that they can be profitably mined only where labor is cheap as in Ceylon. **Flake graphite** is also crystalline but in the form of separate flakes scattered through the enclosing rock, which is crystalline limestone, gneiss, or schist. These deposits are found in the neighborhood of intruding pegmatite dikes, etc., especially those of the gabbro and anorthosite types. Dikes of the granite type do not have graphite ore-bodies associated with them. The richest deposits occur at the crests of rockfolds or at other points where a relief of pressure has occurred during the folding process. This tends to give a saddle shape to the ore-bodies. "**Amorphous**" **graphite** is in crystals so small that they cannot be distinguished without the aid of a microscope. This gives the material a dull appearance. It is commonly found mixed with slate or shale, but sometimes in beds or vein-like masses consisting almost altogether of graphite. Some of these beds have been derived from coal by the action of intense heat. Crystalline and flake graphite are the highest priced. The amorphous variety is not suitable for the manufacture of crucibles.

Uses. About 75% of the world's production of graphite was formerly used in the manufacture of

crucibles and other refractory utensils for metallurgical processes, but the introduction of electrical furnaces has reduced the market for crucible graphite. The increased use of natural graphite for dry batteries has pretty well balanced this loss. The remainder is used as lubricants, pencils, foundry facing, stove polish, paints, in boilers to prevent scale, and for several other purposes. Artificial graphite made by heating anthracite coal or petroleum coke in electrical furnaces is a formidable competitor with the natural material.

Commercial deposits of graphite have not been found in Manitoba.

Reference. Graphite, by Hugh S. Spence, Mines Branch, Ottawa, publication No. 511.

MICA

Introduction. Two members of the Mica family are used in the industries, **white mica** or **muscovite, and amber mica** or **phlogopite**. Most of the mica produced is used in the electrical industries, where its usefulness depends on its insulating power, its incombustibility, and its easy splittng into thin sheets. A third member of the family, **black mica** or **biotite**, sometimes occurs in large "books" or crystals that split nicely, but the high iron content of the mineral makes it a poor insulator for electricity. It has of late been used for making ground mica. The micas are all silicates, but differ somewhat in the rest of their composition. White mica is silicate of aluminum and potassium. Amber mica is silicate of aluminum, potassium

and magnesium. Black mica is silicate of aluminum, magnesium, and iron, with more or less potassium. White mica and black mica have some hydrogen in their composition, and there are other variations. In addition to the three micas mentioned, a number of other minerals belong to the family, but no others are used for the purposes for which white and amber mica are useful.

White and amber mica are common minerals as constituents of such igneous rocks as syenite, granite, etc., but they usually occur in crystals too small to be of any use. To be useful, mica crystals must not only be large, but they must be free from crinkles and cracks, and must not be pierced or stained with other minerals, particularly with oxides of iron that would impair the insulating power of the mica. The quality of the mica is sometimes lowered by thin layers of other minerals such as calcite between the layers of mica. This causes the mica to split unevenly and with difficulty.

White mica of commercial quality is found in pegmatite granite, where all the minerals are in large crystals and more or less separated into bunches, so that the mica, feldspar, and quartz can be taken out separately. Pegmatite dikes are very numerous in Manitoba, but it is only the exceptional dike that contains commercial white mica. These exceptional cases may be looked for around masses of granite, syenite, and gneiss.

Amber mica is found in "pyroxenite dikes," particularly in regions where crystalline limestone is in contact with gneiss and schists. The limestone and

the gneiss occur in bands, and the "pyroxenite dikes" usually follow the strike of these rocks, about northeast-southwest, although in some cases cutting across the strike. These dike-like structures are thought to be metamorphic zones caused by the influence of granite intruding the limestone. The Laurentian granite was itself changed into gneiss. The dull greenish-gray color of the pyroxene rock is a guide in prospecting for the mica.

Uses of Mica. The greater part of the mica produced is used in the electrical industries to separate the copper sheets in armatures and for other insulating purposes. Amber mica is considered to be better for commutators bcause it is not so brittle as most white mica, and wears evenly with the copper. But the Indian white mica is often preferred because of its uniform quality and its superior resistance to heat. A certain amount of the larger sizes is used instead of glass in stove fronts and lanterns. White mica is preferred for these uses, on account of the absence of color and the superior resistance to heat. The waste from the trimming shops is ground to a powder to use on wall paper, to which it gives a silvery, glistening appearance; to mix with rubber, paint, oil and axle grease; for heat-insulating materials; as a coating for roofing paper to prevent the rolls from sticking; mixed with hard rubber for telephone receivers, etc; mixed with shellac, etc., to cover high tension electrical wires. The smaller sizes of mica, smaller than 1 inch x 2 inches, are used in making **micanite** or mica board. The mica is split very thin, from .001 to .005 of an inch, and then built up into sheets of

the desired size by sticking layers of the pieces together by means of shellac. In this way sheets from one-tenth to half an inch thick are made. They are then put under pressure, and finally ground to an even thickness. The sheets can be made of any desired size, and can be cut and shaped.

Prices of Mica. Scrap mica for grinding sells at $5 to $12 a ton. The prices of trimmed mica depend on the size, from 10 cents a pound for 1 x 3 inches, to $1.50 to $2.00 a pound for 5 x 8 inches. Larger sizes are sometimes required for special purposes and bring correspondingly higher prices.

Pegmatite dikes are numerous along the east shore of Lake Winnipeg between Belanger Point and Big Black River. In some of these dikes large crystals of white mica are to be seen. It is possible that some of these dikes may prove to contain merchantable mica.

There are many pegmatite dikes in the Oiseau River area (See **Feldspar** p. 166). Some of these may contain white mica of commercial quality.

References: Geological Survey of Canada, New Series, Vol. XI, p. 24 G.

Mica, by Hugo S. de Schmid, Mines Branch, Ottawa, publication No. 118.

PHOSPHATE

Introduction. This name is used in commerce to designate all kinds of minerals composed essentially of phosphate of lime including the mineral **apatite,** formerly extensively mined in Ontario and Quebec, but now superseded by a sedimentary deposit that

can be very cheaply mined in Florida and other southern states. The Canadian apatite deposits are comparatively small and involve the kind of mining usually applied to veins. The apatite occurs in bunches, and the pyroxene, mica, etc., accompanying it must be mined as waste, although the mica is sometimes of commercial quality. Florida phosphate can be delivered in Eastern Canada for less than the cost of mining apatite. This fact alone is responsible for the almost complete cessation of phosphate production in Ontario and Quebec. Apatite differs from the Florida phosphate in being a definite crystallized mineral that can be obtained pure and unmixed with the clay, sand, etc., that dilute Florida phosphate. While these inert materials do not interfere with the principal use of phosphate, namely the manufacture of agricultural fertilisers, they reduce the percentage of phosphoric acid, the fertilising part of the material. These impurities may also make the sedimentary phosphate unsuitable for the manufacture of new substances containing phosphorus.

Uses of Apatite. The principal use is for the manufacture of acid phosphate or **superphosphate** to supply the phosphorus needs of crops, and for the manufacture of phosphorus. For use as a fertiliser, the value of the phosphate depends on the percentage of phosphate of lime, which is much higher in Canadian apatite than in Florida and Tennessee phosphate, which analyses 77 to 72% of phosphate of lime, while pure apatite contains about 90% and the mineral can be mined and cobbed to an 85% product.

No apatite deposits of economic importance have been discovered in Manitoba. The only known deposit of phosphate of possible commercial importance is a small bed of phosphatic shale on Wilson River, west of Lake Dauphin. The shale is filled with small fragments of bones and teeth of fishes, giving the rock a phosphate content equivalent to 37.70 per cent of calcium phosphate. The thickness of the shale bed is small, and its lateral extent is unknown. It is of Cretaceous age.

Apatite occurs in small quantities in the lithium deposits of the Bernic Lake area.

TALC

The mineral talc is a hydrated silicate of magnesia, and is usually a product of the alteration of other minerals rich in magnesia, such as pyroxene, olivine and dolomite. The purer, light-colored deposits of talc suitable for making talcum powder, etc., are found in dolomite from which the talc has been formed by the action of siliceous material from intrusions of igneous rocks. The fine-grained, dark-colored deposits are formed by the alteration of such basic rocks as diabase, gabbro, and peridotite, which ar econverted into serpentine and talc by the influence of igneous intrusions. This massive talc is usually less pure than the white well-crystallized variety, and the impurities make it harder than the pure mineral. The fineness of its grain and its hardness make it useful to saw and carve into table tops, sinks, switchboards, bricks for lining furnaces, etc. The massive variety is sometimes pure enough to grind to a white powder.

The lighter colored varieties are used also for making gas light tips and for marking (French chalk). The less pure, fine-grained varieties of talc are generally called **soapstone**. Discoveries of crystallized talc may be looked for in dolomite and serpentine. Massive talc and soapstone may be found wherever highly basic rocks have been subjected to the transforming action of liquids derived from igneous intrusives. As basic lava, gabbro, diabase, and peridotite are fairly common in the Precambrian of Manitoba, there should be a good many bodies of soapstone to select from and draw upon.

Canadian pulp mills are using about 2,500 tons of soapstone a year, as lining for the alkali-recovery furnaces.

Talc deposits of commercial importance have not so far been found in Manitoba. In the Flin Flon district there are extensive areas of basic volcanic rocks, and in places these have been altered to talc. The presence of talc in the Flin Flon copper-zinc ore deposit caused some difficulty in the concentration and separation of the ore. There may be places in the district where the metamorphosis of the basic volcanics has produced commercial soapstone suitable for furnace linings, etc.

ASBESTOS

Fibrous varieties of several minerals have been used as asbestos. The material originally employed to make fire-proof cloth, etc., seems to have been fibrous hornblende. In modern times this has been displaced by fibrous serpentine, the fibres of which are not so

brittle as those of hornblende, and therefore spin and weave better. Crocidolite, the blue asbestos of South Africa, is a silicate of iron and sodium.

Asbestos of the fibrous serpentine kind occurs in serpentine that has resulted from the alteration of dunite, peridotite, and other rocks high in magnesia. Where this alteration has taken place on a large scale (regional metamorphosis), the asbestos is more likely to be of good quality and important in quantity. Smaller deposits of poorer quality occur where the alteration has taken place at contacts with dikes and other small bodies of igneous rocks (contact metamorphism).

Uses. Asbestos of the various grades has a great many uses and its use is constantly extending. The spinning grades are made into firemen's suits, mitts for furnace workers, etc. The lower grades are used for the manufacture of shingles, sheeting, roofing paper, cement, insulating packings of various kinds, wall boards, etc. In the automobile industry, asbestos is used in making brake linings and clutch facings.

No commercial deposits of asbestos have so far been found in Manitoba.

CHAPTER XI

NON-METALLICS (Cont'd)

BARIUM, STRONTIUM, LITHIUM, MAGNESIUM

BARIUM

The metal barium is a rather soft, gray metal, very easily oxidised and not of importance commercially. The most important barium minerals are the sulphate, **barite**, and the carbonate, **witherite**.

Barite

The common filling of veins is quartz and calcite. Less common fillers are fluorspar, barite and celestite. These materials may therefore be found wherever there are veins. They may be mixed or occur in veins mainly filled with quartz or calcite. Veins of barite, celestite, or fluorspar may carry valuable metallic minerals and thus become ores of lead, zinc, copper, etc. Other names for the mineral are **barytes** and **heavy spar**. The chemical name is **barium sulphate**, indicating its composition, the metal barium with sulphur and oxygen.

While barite veins are plentiful and widespread, as in the case of other valuable minerals it is only the exceptional vein that can be profitably mined. One of the important uses of barite is as a constituent for white paints. For this purpose it must be free from all minerals that would destroy the purity of the white, when ground to a very fine powder. This requirement cuts out barite veins that carry considerable quantities of pyrite and other sulphides.

Uses of Barite. Ground barite is used as a filler in paper, cloth, oil-cloth, rubber, linoleum, etc. and as a substitute for white lead in making white paint. In the manufacture of enamelled paper, ground barite is used as filler and also for surfacings. It is used as a filler in the manufacture of artificial ivory and in many other materials where a crystalline body of material is required. Barite has the advantage of its chemical inertness, making it not liable to any change. It is useful as an addition to certain kinds of glass, enamel and glaze. For the manufacture of ground barite, manufacturers prefer the soft, very fine-grained variety.

Lithopone is a white paint material made from barite by passing it through a chemical process that gives as a final product a mixture of about 70 per cent barium sulphate and 30 per cent zinc sulphide. Part of the zinc sulphide may have been changed to zinc oxide. All these substances are pure white when not mixed with anything colored. Lithopone is extensively manufactured for white paint, as a rubber filler, etc., and is sold under a good many other trade names. The hard, crystalline barite can be used for

this manufacture, even when stained with iron rust, as the chemical process eliminates this.

Barite is used as the starting point in the manufacture of a number of barium chemicals, such as **blanc fixe,** artificial barium sulphate of the same composition as barite, but purer and finer grained, **barium carbonate,** used in the manufacture of optical glass, enamels, etc., and many other barium chemicals.

Barite occurs in veins in serpentine on Pipestone Island, Lake Winnipeg (Geological Survey of Canada, New Series, Vol. XI, p. 54G). It is also reported near Pipestone Lake. No commercial deposits have been observed in the province.

STRONTIUM

Strontium is a metal closely allied to calcium, the metal of which lime is the oxide. Barium is the third metal of this group. They are all rather soft, gray metals, very easily oxidised, and therefore by themselves not useful as metals. Strontium has been used as a hardener of copper castings.

The principal strontium minerals are **celestite,** the sulphate of strontium, and **strontianite,** the carbonate of strontium. Celestite is the commoner mineral, and is by far the most important source of the world's supply of strontium minerals. Strontianite brings a higher price because it contains a higher percentage of strontium oxide, and because it is more easily converted into the commercial products.

Celestite is a soft, rather heavy mineral, white creamy, or pale blue in color. It is much like barite

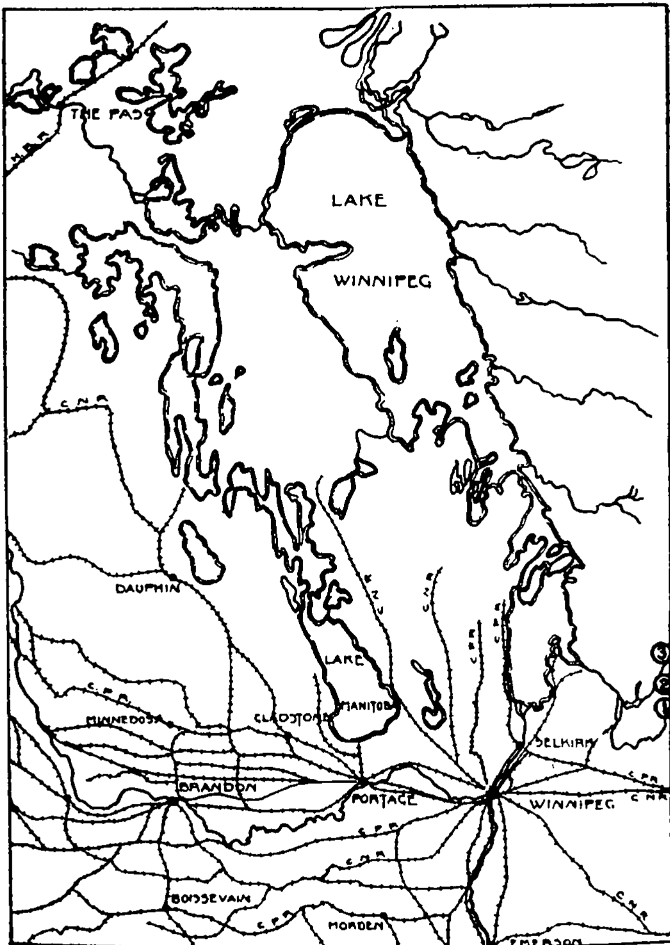
but not quite so heavy. Its crystals are sometimes long and arranged in such a way as to give the mass a somewhat fibrous appearance. It occurs in veins, sometimes with calcite, fluorspar, barite, and metallic vein minerals. Celestite may contain more or less barite crystallized with it. When the amount is considerable, the mineral is called **barytocelestite.** The mixed mineral is not so valuable as pure celestite, and if the percentage of barite is high, the mineral may be unsaleable.

Strontianite is a white, yellow, or greenish mineral, usually in masses of crystals having a radiated, columnar, or fibrous appearance. It is a soft and rather heavy mineral.

Celestite and strontianite are the raw materials for the manufacture of a number of strontium compounds, including strontium hydrate, used in the manufacture of beet sugar, strontium nitrate for making red lights for fireworks and signal flares, and a number of chemicals. Celestite has been used instead of barite (barytes) as a filler and in the manufacture of lithopone. Strontium carbonate is used in the manufacture of iridescent glass. The use of the metal strontium for hardening copper castings has been carried out either by adding it to the fused copper or by generating it from fused strontium chloride using the melted copper as a cathode in which to deposit the strontium.

The market prices for the strontium minerals are (1928), for celestite \$15 to \$18 a ton, and for strontianite \$25 to \$35 a ton.

Strontianite is a rare mineral, and there are very few economic deposits known in the world,



LITHIUM PROPERTIES
1. Silver Leaf Mining Syndicate.
2. Bernic Lake Property (K. E. Miller)
3. Cat Lake Property

No strontium minerals have been reported in Manitoba.

LITHIUM

The metal lithium is related to sodium and potassium. It has so far not assumed any economic importance, but a number of its compounds have been made useful in medicine, and some of the lithium minerals have found applications in the manufacture of glass. As the lithium minerals are not often found in commercial quantities, a workable deposit is valuable. **Lepidolite** or **lithium** mica resembles the commoner varieties of mica, but is more brittle, and is usually of a pink, rose-red, violet, lilac, or yellow color. It is sometimes gray, grayish white or white. It is found in dikes of pegmatite granite. Two other lithium minerals, **amblygonite** and **spodumene,** are also found in pegmatite dikes, and sometimes in gneiss. Amblygonite and spodumene might be easily overlooked in these rocks as they are often of an inconspicuous gray or whitish color. Spodumene is sometimes green, yellow or purple. The lithium minerals sell for $20 to $30 a ton.

Silver Leaf Mining Syndicate

The property of this company is on Section 17, Township 16, Range 16 East, one mile south of Winnipeg River and about 3¾ miles from Lamprey Falls. The nearest railway shipping point is about 12 miles southwest at Point du Bois, which can be reached by motor launch from Lamprey Falls, a distance of 8 miles. The chief lithium mineral in one part of the deposit is lepidolite, but spodumene and amblygonite

also occur plentifully in places, and spodumene is on the whole, the most plentiful lithium mineral. These minerals are found in a pegmatite dike along with quartz and feldspar. The dike cuts andesite schist and is 80 ft. wide, so far as uncovered, and lithium minerals occur over a length of 425 feet or more. The greater part of this length is under a muskeg where the pegmatite has been followed by diamond drill holes. Analyses of selected specimens give 3.87 to 5.23 per cent of lithia (lithium oxide). An area about 90 feet long and 40 feet wide is mostly spodumene-bearing rock, about a third of which is lithium ore that can be hand-picked. One lepidolite lens is 30 feet long with an average width of 15 feet. Another is 18 feet long and averages 10 feet in width. The lepidolite is in clean masses requiring no cobbing. It is of a reddish lilac color, the peculiarity of which first attracted the attention of prospectors. A considerable amount of ore has been taken out and shipments made to England, Germany, and the United States.

Bernic Lake Area

Lithium minerals occur plentifully in pegmatite sills on both sides of a creek that flows into the northeast bay of Bernic Lake. Amblygonite and spodumene are the most plentiful, but lepidolite occurs in small quantities. Some of the spodumene crystals are over two feet long, and large crystals of amblygonite occur. These deposits are economically important.

Cat Lake Area

Cat Lake is about 10 miles north of Bird River in Tp. 19, Rge. 15E. The Irgan lithium claim is about

half a mile north of the lake. A pegmatite dike has been exposed for 1200 to 1500 feet. Its width varies from 15 to 70 feet. Spodumene is most plentiful on the hanging wall side of the dike, and in places half the width of the dike may be considered as lithium ore. A large body of ore is indicated.

About half a mile south of Cat Lake is a pegmatite dike that shows lithium minerals in considerable amounts over a length of 100 feet. The principal lithium mineral is spodumene. Spodumene has also been observed in a number of deposits a short distance south of the east end of Cat Lake, but the showings are irregular and rather difficult to follow.

References: The Non-Metallic Mineral Resources of Manitoba, by R. C. Wallace and L. Greer, Industrial Development Board of Manitoba, Winnipeg, 1927.

Geological Survey of Canada, Summary Report, 1924, Part B, page 100.

Lithium-bearing minerals in Canada, by L. H. Cole and V. L. Eardley-Wilmot, Mines Branch, Ottawa, publication No. 669.

Lithium Minerals in Southeastern Manitoba, by Hugh S. Spence, Mines Branch, Ottawa, 1928, publication No. 687.

MAGNESITE AND MAGNESIUM

Magnesite is carbonate of magnesia. When pure, it is a white mineral, much like calcite, but harder and a little heavier. One variety shows no crystalline structure and looks much like a piece of broken porcelain, but it is not so hard.

Magnesite is found in serpentine, talc schist and other varieties of metamorphic rocks, and also in dolomite.

It is used largely for making magnesia bricks. Magnesia is the oxide of magnesium. In commerce it is often called magnesite. It is made by heating magnesite to drive off the carbon dioxide. This is the same kind of process as making lime from limestone, but the temperature required for decomposing the limestone is much higher. Magnesia bricks are used for lining electric, basic-steel, copper smelting, and other furnaces; also for sulphite pulp manufacture, fireproof flooring, and for making magnesia medical and chemical materials. Magnesite is the raw material for the manufacture of the metal magnesium.

Magnesite has not been found in commercial quantities in Manitoba. It may be discovered in altered basic rocks that are plentiful in the Precambrian of Canada.

CHAPTER XII

NON-METALLICS (Cont'd)

PRECIOUS AND SEMI-PRECIOUS STONES

Gem stones. Precious stones are mostly crystallized minerals, and each gem is usually made from a single crystal or part of a crystal. The mineral must be hard enough to be durable and keep its polish under wear. While some gem stones are opaque, the majority are transparent, and any cloudiness, cracks, or inferiority in color may lower their value or make them valueless as gem stones. The conditions for the growth of good crystals, such as slow cooling, the presence of mineral solvents to keep the mass liquid, and the formation of small cavities into which crystals could grow without too much crowding **(vugs** or **geodes)** have been present during the formation of many of the crystalline rocks of Manitoba, and probably in the earlier ages gem stones were formed freely. But the folding, re-heating, and crushing that have since taken place, must have destroyed the perfection of most crystals of gem quality. Pegmatite dikes are the home of a large variety of precious stones, including ruby, sapphire, beryl (emerald, aquamarine), chrysoberyl (alexandrite, chrysolite,

cat's eye), phenacite, topaz, garnet, tourmaline, zircon (hyacinth or jacinth), and sphene.

While precious stones have not so far been observed in Manitoba, there is the chance that crystals of gem quality may have formed in some of the numerous pegmatite dikes and in other crystalline rocks, and may have escaped the severe conditions that have prevailel since these rocks were formed. It is thought to be worth while to give here a short description of the principal kinds of gem stones for reference.

The weight of gems is given in terms of a special unit, the **carat,** which is very nearly equal to 3½ grains. One ounce Troy equals 151¾ carats very nearly.

In describing gem stones or **precious stones** some are included that are less valuable and that are usually classified as **semi-precious stones.**

Amazonstone. Also called **amazonite.** The variety of feldspar, **labradorite,** is called by this name when it is of a fine blue color that changes as the stone is turned, the **chatoyant** effect. Another feldspar, **microcline,** has been found of a fine green color. The labradorite variety of amazonstone is found in large quantities in the Hamilton River district, Labrador.

Agate, see **Quartz**
Alexandrite, see **Chrysoberyl**
Amethyst, see **Quartz**
Aquamarine, see **Beryl**
Aventurine, see **Sunstone**

Beryl. This is a silicate of aluminum and beryllium. The color of the crystals is usually green, but beryls

of blue, yellow, rose-red and white shades are found. Clear green crystals of gem quality are called **emeralds**. Blue-green crystals are used as gems under the name **aquamarine**. Beryl crystals are six sided prisms. The hardness is greater than that of quartz. Beryl is found in pegmatite dikes and in the rocks intruded by them. Valuable beryl crystals have been obtained as a by-product in mining white mica.

Beryl occurs occasionally in the pegmatite dikes of the Oiseau River district. Beryl crystals in the lithium pegmatite dikes at the northeast end of Bernic Lake may be of gem quality. Some of them are transparent and of good color.

Cairngorm, see **Quartz**

Cat's Eye, see **Chrysoberyl**

Chrysoberyl. This is an oxide of aluminum and beryllium. Jewellers call the yellow variety **chrysolite,** but mineralogists apply this name to olivine. The green variety is valued as a gem and is called **alexandrite**. A green variety that shows the peculiar play of colors described as **chatoyant,** is called **cat's eye.** Chrysoberyl is very hard and the crystals are apt to be tabular. It is found in pegmatite dikes and in rocks in contact with them.

Chrysolite. see **Chrysoberyl** and **Olivine.**

Corundum. This is oxide of aluminum, found in rocks of the granite type, such as syenite and nepheline-syenite, also in anorthosite, peridotite, serpentine and other basic igneous rocks. The jewel varieties of corundum are **ruby,** clear crystals of a red colour, and **sapphire,** blue corundum crystals. To be of value the crystals must be transparent and free from cracks and

other flaws. In New York and New Jersey, rubies have been found in crystalline limestone. In North Carolina they have been found in an olivine dike, the olivine being partly altered to serpentine. In Burmah, long the producer of the finest rubies, they are found in crystalline limestone and gneiss. Sapphires have been found in crystalline limestone and in andesite. Crystals of these gems can be recognized by the six-sided prismatic shape, and by their great hardness. They easily scratch quartz crystals. Corundum crystals of gem quality should be watched for in crystalline limestone and gneiss.

Diaspore, a hydrated oxide of aluminum, is sometimes found with corundum. It is about as hard as quartz or a little softer. The crystals are commonly colorless, but sometimes yellowish like topaz or brownish.

Diamond. The diamond is carbon crystallized under conditions not fulfilled in furnaces and fires. Graphite is also crystallized carbon, and it can be made artificially from coke by intense heating. Microscopic diamonds have been made by sudden cooling of intensely heated carbon under certain conditions, but all attempts to make diamonds of gem size have so far failed. The natural stones are found in peridotite and serpentine, and in the soft material that results from the weathering of these rocks. In Brazil they are found in a peculiar flexible sandstone, **itacolumite.** Diamonds of gem size have been found in the glacial drift in Wisconsin. On account of their great hardness and durability, diamonds survive longer than other minerals the wear and tear of the ages. They should be watched for in panning.

Diopside. This is a variety of pyroxene, sometimes found in fine emerald-green crystals of value as gems. They may occur in crystalline limestone or in the pyroxene rock often associated with it.

Fluorspar. When in large, clear masses of a fine color, fluorspar is of value as an ornamental stone, for making vases, etc. As it is only one degree harder than calcite it is easily worked. On the other hand it is not hard enough to be very durable.

Garnet. Garnet crystals are sometimes perfect and clear enough to be of value as gems. Most of the varieties of the mineral are used as gems when transparent crystals are found. Jewelers use red and yellowish brown garnets under the name **hyacinth**. The smaller crystals are used as jewels in the movements of watches, but the harder crystals of ruby and sapphire are preferred.

Garnet in mica schist at the east end of Anderson Lake, west of Herb Lake, occurs as large, well-formed crystals suitable for museum specimens, but not of gem quality. At Oxford Lake there are small garnets of good color in gneiss.

Gem garnets are found in serpentine, crystalline limestone and other metamorphic rocks. Very fine gem garnets have sold for as much as $50 each. Good crystals of one carat weight have been valued at $1 to $5 each.

Hyacinth, see **Garnet** and **Zircon.**

Jade, also called **nephrite,** is a silicate of calcium, magnesium and iron. Green varieties of pyroxene and hornblende are included under this name.

Jasper, see **Quartz.**

Moonstone, or peristerite, is the name given to the varieties of feldspar, albite and orthoclase, when they show the chatoyant play of colors, usually delicate shades of blue and green.

Olivine, see **Peridot.**

Peridot is the jeweler's name for olivine crystals. Olivine is a silicate of magnesium and iron, usually of a green color. The crystals may be found in basic igneous rocks and in some kinds of dolomite.

Peristerite, see **Moonstone.**

Perthite. This is an ornamental stone that owes its beauty to parallel layers of two feldspars, orthoclase and albite. The layers give the internal reflections of light characteristic of aventurine or sunstone. The mineral takes its name from the town of Perth, Ontario, near which it was first found. There it is flesh-colored, but it has been found of other colors..

Phenacite, a silicate of beryllium, may be looked for in pegmatite dikes. It forms colorless crystals, very brilliant. It looks a good deal like quartz, but is harder, and the crystals are of a different shape. (See **Handbook for Prospectors p. 297**).

Quartz. A good many varieties of quartz are used as jewels and ornamental stones. Clear, colorless, flawless quartz crystals of sufficient size are ground into spheres which, when large, are valued at thousands of dollars. Necklaces anl other jewels are made of quartz crystals cut under the name **rock crystal.** The United States Navy offers $6,000 a ton for per-

fect quartz crystals weighing not less than 2 pounds each. They must be transparent and free from cloudiness, cracks, and spots. They are used for controlling the frequency of radio transmitters. Pink to purple crystals are used under the name **amethyst.** Smoky crystals are used as **cairngorm. Sagenite** or flêche d'amour is quartz crystals penetrated by fine needles of rutile. These and other varieties of crystallized quartz are found in pegmatite granite and other acid rocks. They are to be looked for in vugs (geodes) in those rocks. Cavities in sandstone and quartzite have yielded very fine crystals of quartz. **Jasper** is a variety of quartz usually of a red color. It is occasionally associated with **chalcedony**, another variety of quartz. Bright red jasper is sometimes set in a white mass of quartz making a very pretty combination. Jasper in banded iron formation occurs near Grass River, Northern Manitoba, and in the Rice Lake area.

Rock Crystal, see **Quartz.**

Rose quartz is found in considerable quantities in a pegmatite dike one third of a mile north of the east end of Birse Lake, in the Oiseau River area. The mineral is of a fine color and is largely transparent.

Ruby, see **Corundum.**

Star quartz or **quartz asteria** is a variety of clear, transparent quartz that when cut in a certain way shows a six-rayed star.

Sagenite, see **Quartz.**

Sapphire, see **Corundum.**

Serpentine is a hydrated silicate of magnesium. When of a rich green or greenish yellow color, it is

of value as an ornamental stone, although its softness makes it of inferior durability. It can be used only for interior decoration as its polished surface soon weathers when exposed out of doors.

Sodalite. This is silicate of aluminum and sodium with sodium chloride. It varies in color, but the deep blue variety is sought for ornamental purposes.

Sphene or **titanite** is calcium titanium silicate. When found in transparent crystals it is prized as a gem.

Spinel is an oxide of magnesium and aluminum. Some varieties contain iron or chromium. The common color of gem spinel is ruby red but other colors may give value to good transparent crystals. The crystals are usually octahedrons of the cubic system. Ruby spinel is sometimes found with the true ruby, the crystals of which are six-sided prisms. Spinel is found in crystalline limestone, serpentine, peridotite, etc.

Sunstone or **aventurine** is a variety of feldspar showing peculiar fiery reflections probably due to small crystals of hematite, etc. A variety of quartz showing this effect is also called aventurine.

Topaz. The usual color of topaz crystals is honey-yellow. They are found in vugs in pegmatite granite, rhyolite, and other acid rocks, and also in schists. The crystals are apt to be long and with a pointed end. The finest crystals sell for as much as $100 each. Topaz has been occasionally noticed in the pegmatite dikes of the Oiseau River area.

Tourmaline is a silicate of complex composition. The common color is black. When in fine clear cry-

stals of a pink, red, or green color, it is of value as a gem. Tourmaline crystals can be recognized by their triangular cross section. They are usually more or less distinctly grooved lengthwise. The crystals are to be found in pegmatite dikes and at the contact of intrusive granite with such metamorphic rocks as gneiss, schists, and crystalline limestone.

Rather fine tourmaline crystals have been noticed in the pegmatite dikes of the Oiseau River area.

Zircon is a silicate of zirconium. Zircon crystals are usually of an opaque brown color. They can be recognized by the square cross section and by their hardness, a little greater than that of quartz. Clear crystals of a rich red color are used as gems under the name **hyacinth** or **jacinth**. Orange or brown crystals when transparent may be of value. Crystals suitable for gems may be found in pegmatite dikes and at contacts of igneous intrusives with metamorphic rocks, particularly crystalline limestone and nepheline syenite.

Pegmatite dikes and sills are numerous in the Cold Lake area, Northern Manitoba. They have not been searched for gem stones. Discoveries may be made when they are examined carefully (J. F. Wright, Canadian Mining and Metallurgical Bulletin, April, 1929, p. 535).

Anhydrite occurs in large quantities northeast of Gypsumville. It has been proposed as suitable for interior decoration, as it is hard enough to take a fine polish so as to show bluish gray and red tints. It is not suitable for exterior work, as it goes to pieces when exposed to weather.

Fuchsite, or chrome mica, occurs in the pegmatite dikes of the lithium area east of Point du Bois, Winnipeg River. It is of a deep green color and suitable for use as stucco "dash."

Amber. A fossil resin allied to amber is found in the clay on the beach and raised beaches of Cedar Lake, near the Chemahawin Post of the Hudson Bay Company. It occurs in lumps, varying in size from a pea to a hen's egg, the average size being less than ½ inch in diameter. The name **chemahawinite** has been given to the material. It is suitable for the manufacture of varnish, but is mostly not clear enough to be used as an ornament. The same material has been found in some of the bays at the south end of Moose Lake.

Reference: The Non-Metallic Mineral Resources of Manitoba, by R. C. Wallace and L. Greer, Industrial Development Board of Manitoba, 1927.

CHAPTER XIII

NON-METALLIC MINERALS (Cont'd)

SALT, GYPSUM, PETROLEUM AND NATURAL GAS, HELIUM, COAL, CLAY

SALT

Salt has the chemical name **sodium chloride**, which indicates its composition. Its common uses are too well known to require description. One point, however, in connection with its use in food merits attention. The natural sea salt has mixed with it small quantities of iodine compounds that are a necessary constituent of our food. These materials are removed in the process of refining the salt. Their absence from table salt does not matter for those living near the sea board, where all the food is apt to be well seasoned with natural salt and even the air carries it as dust. But people living far inland, and particularly those in regions where the rocks are either igneous or very old sedimentaries that have lost all traces of salt that they may have acquired from the ocean, may suffer from diseases like goitre due to deficiency of iodine in the food. Since this has been realized, manufacturers of

table salt usually add enough potassium iodide or other iodine salt to their products to make up the deficiency.

Salt is the raw material for a large number of important chemical manufactures, including soda (caustic and carbonates), sodium, chlorine, chloride of lime, and many others.

Salt is found in economic quantities only in those sedimentary rocks that have not undergone much, if any, metamorphism, and are still lying approximately in the horizontal layers in which they were formed. It is believed that the salt has been deposited by the evaporation in a dry climate of parts of the ocean barred off from the main body by some change in the bottom. Gypsum and other constituents of ocean water are often found associated with layers of **rock salt,** as the solid natural salt is called. (See **Gypsum** p. 209). But it is believed that some bodies of rock salt as we find them now have been deposited by the slow leaching and transportation of older salt deposits.

Salt springs are natural brines that may be (1) sea water imprisoned by geological changes, (2) solutions formed by ground water working on beds of rock salt, or (3) solutions of salt made by the slow collection of salt from the sedimentary rocks and its concentration by slow evaporation. It is thus seen that salt springs may or may not be a sign of underlying beds of rock salt.

Rock salt deposits have been found in sedimentary rocks of all ages from recent back to the Silurian period. Salt brines have been tapped in drilling wells

in even older rocks, but these may have been derived from rocks higher up in the geological scale.

For more than a century salt springs have been known in the district west of Lake Winnipegosis, and salt was manufactured there by rather crude methods as early as 1820. Evaporation in pans was carried on at the Salt Springs, Red Deer Peninsula. Later, salt was made at Swan River and Duck River. The brine from these springs is comparatively weak, averaging only 5.5 to 6 per cent of dissolved salt in the area west of Lake Winnipegosis. The Ontario brines contain from 23 to 25 per cent. As the cost of manufacture depends mostly on the amount of water to be evaporated, it is seen that these Manitoba brines cannot compete with those in Ontario. However, a well bored near Neepawa yields a brine with 19.08 per cent of dissolved salts.

Salt springs are very numerous and appear in a narrow belt extending from Carrot River near the Saskatchewan boundary in a southeasterly direction to the international boundary east of the Pembina Mountains. This belt is 320 miles long and about 40 miles wide. It is underlain largely by rocks of Devonian age, and the most important springs, west and south of Lake Winnipegosis, issue from Devonian limestone and dolomite. It is calculated that the salt springs of Manitoba are discharging about 52,500 tons of dissolved salts a year, of which 85 per cent is sodium chloride. The sources of the salt have not been discovered. The well at Neepawa is 1600 feet deep. It did not pass through a rock salt layer but tapped brine flows at 1225 and 1455 feet. Other wells at James-

town, Deloraine, Rosenfelt, Morden, Manitou, Gladstone, Rathwell, and Winnipeg also tapped salt water but failed to show rock salt. The well at Elmwood Sanatorium struck flows of weak brine at 477 feet and 567 feet.

The brine has been struck in, or flows naturally from, rocks of four ages, namely (beginning with the youngest), (1) Devonian limestone and dolomite, as in the case of the springs west and south of Lake Winnipegosis; (2) in or near the Silurian gypsum beds, as seen in the Rathwell well; (3) Ordovician limestone, for example, the Neepawa well; and (4) Ordovician sandstone, at the base of the series, where the Elmwood brine was tapped.

Of all the salt springs and wells in Manitoba, the well at Neepawa is the only one yielding brine strong enough to compete with those of Ontario. If pumping shows that the brine of this well maintains its concentration of from 17 to 19 percent, it may be profitably worked as a source of salt. More extensive borings may reveal layers of rock salt.

It is possible that preliminary evaporation of the brine from the salt springs by the heat of the sun might be used as the foundation of a profitable salt industry. It has also been suggested that this might be combined with concentration by freezing in the winter. As is well known, pure ice forms, and leaves a stronger brine. This concentration can be carried to a certain point at which ice and salt solidify together. Both solar evaporation and the freezing method have been used in the manufacture of salt from sea water.

Some of the springs and wells yield brine carrying

appreciable quantities of bromine, iodine, and potash salts.

References: The Salt Deposits of Canada, by L. Heber Cole, publication No. 325, Mines Branch, Ottawa.

The Non-Metallic Mineral Resources of Manitoba, by R. C. Wallace and L. Greer, Industrial Development Board of Manitoba, Winnipeg.

GYPSUM

Introduction.— Gypsum is sulphate of lime crystalized with water. When it is carefully heated so as to deprive it of the greater part of its water but not all of it, it is converted into plaster of Paris. When this is mixed with the right quantity of water, it becomes gypsum again, and in the act forms a mass of small crystals. This is the "setting" of plaster of Paris, the property upon which its usefulness depends. Gypsum, when pure, is white. It is soft enough to be scratched by the finger nail. It is often massed in crystals so small that it looks a good deal like chalk, but usually, in bright light, the glistening surfaces of small crystals can be noticed. Sometimes single crystals have grown so large that they form masses as clear and transparent as glass. These have a special name, **selenite.** Selenite crystals can be split into thin sheets like mica, but differing from mica in having no elasticity. A fine-grained translucent variety of gypsum is called alabaster. Satin spar is a variety composed of fine parallel fibres.

Gypsum in commercial quantities is always found in sedimentary rock formations, such as shale and lime-

stone, and often associated with rock salt in such a manner as to suggest that both have been deposited by the evaporation of bodies of sea water. This could have happened by the separation of lagoons or bays from the rest of the ocean in such a way that in a dry climate the water evaporated faster than it was renewed. The occurrence of very great thicknesses of gypsum and salt can be explained by the flow of sea water through very narrow openings into such lagoons or bays to take the place of the water as it evaporated. Such nearly closed-off portions of the ocean can be now seen on the earth. There are other suggested explanations of the occurrence of layers of gypsum.

Anhydrite is sulphate of lime without the water that is part of the composition of gypsum. It is often found with gypsum. It is much harder than gypsum. Owing to the absence of water in its composition, it cannot be used instead of gypsum, but the occurrence of large quantities in some countries has stimulated research into possible uses. It can be converted into gypsum by grinding it very fine with water, but the process can hardly be commercially successful, so long as large supplies of gypsum are available. Much of the material formerly reported as gypsum has proved on closer examination to be anhydrite. In the gypsum formations, the anhydrite is found below the gypsum. There may be an intermediate zone where the two minerals are mixed.

Uses. Gypsum is used as a fertilizer for land, and so is often called **land plaster. Raw** or **uncalcined gypsum** is used principally to mix with Portland cement

as a "retarder" that is, to lengthen the time of setting. It is added in the proportion of 2% to the cement clinker as it comes from the roaster. Finely ground gypsum is sometimes mixed with barnyard manure in which it helps to retain the ammonia. Used by itself it has been found advantageous to crops of clover, beans and peas. It has found some uses as a flux in smelting lead and nickel ores, for filtering some kinds of oils, for phonograph records, for buttons, for black board crayons, as a base for paints, and to dilute certain insect poisons including Paris green, as a filler for paper and cotton, and as a body for asbestos packing and gaskets.

For its principal use as **plaster of Paris** or **stucco,** gypsum is **calcined,** that is, carefully heated until three quarters of its water is driven off. The resulting plaster of Paris is used as a finish over lime-sand plaster and in other places as "hardwall." "hard finish," and "flooring plaster," and in the manufacture of wall-boards, tile, and blocks for interior construction. Smaller uses are for interior wall decorations, moulds and patterns, casts of art objects, surgical and dental casts, safe construction, match heads, as a base for cold water tints, and to some extent in oil paints.

Gypsum blocks are made by casting plaster of Paris into the desired shape and size after mixing with water and shavings or excelsior. The blocks are then air-dried or dried by steam heat. They are used for partitions, firewalls, furring of walls and for heat insulation. They possess the advantages of lightness and fire resistance. In addition they can be sawn,

bored, and in other ways shaped and worked. Their use as a construction material is increasing fast.

Gypsum board or **plaster board** is made in a similar way, using plaster of Paris mixed with sawdust, wood fibre or other material such as corn starch or dextrin to increase the toughness and lightness. It is sold under the name **gyproc** wall board.

For **wall plaster** the plaster of Paris is mixed with various materials (retarders) to increase the time of setting.

Insulex is made by mixing aluminum sulphate and finely ground limestone with plaster of Paris. When this is mixed with about half its bulk of water it swells to four or five times its original bulk, and sets in 20 or 30 minutes to a finely porous mass of very high heat-insulating power. The swelling is caused by the liberation of carbon dioxide from the limestone by the action on it of aluminum sulphate.

LAKE ST-MARTIN

Gypsum deposits are widespread in the province, but in only one area has it been found sufficiently near the surface to permit of profitable working. This locality is northwest of the narrows of Lake St. Martin, a small lake east of the north end of Lake Manitoba. This district is connected with Winnipeg by a branch of the Canadian National railway which has its northern terminus at Gypsumville. The area over which gypsum outcrops have been traced is about 7 miles north and south by 8 miles east and west. It is characterized by north-south ridges rising about 60 feet above the level of Lake St. Martin with swampy land between them. Sink holes, small caves, anl deep

depressions, characteristic of gypsum country, are frequent, and the deposits are covered by a light overburden. In the quarry of the Canadian Gypsum and Alabastine Company, a depth of 150 feet of gypsum has been proved, and it has been calculated that about 130,000,000 tons of gypsum is indicated in the district. In places, anhydrite is found with the gypsum.

About 6 miles northeast of the Canadian Gypsum and Alabastine Company's quarry is the deposit known as Elephant Hill, where a 15-foot bed of selenite and pure, fine-grained gypsum is quarried for the manufacture of plaster-of-paris.

On sections 3 and 10, Tp. 33, Rge. 8W, is a deposit of anhydrite at least 100 feet thick, and another, at least 22 feet thick, occurs on section 31, Tp. 32, Rge. 8W. It has been suggested that this stone might be used for interior decoration. In hardness it is equal to marble, which it resembles when polished.

These gypsum deposits are of upper Silurian age, probably corresponding with the deposits worked in Ontario.

FAIRFORD

Near Fairford, 15 miles south of Gypsumville, gypsum was struck at a depth of 75 feet in boring a well.

ASHERN

This place is 45 miles south of Gypsumville. A two-foot bed of gypsum was struck at a depth of 40 feet.

VERMILION RIVER

A bore hole put down at a point 75 miles southwest of Gypsumville passed through 15 feet of gypsum at

a depth of 550 feet. This bed is thought to be of Devonian age.

SOUTHERN MANITOBA

Beds of gypsum ranging from 5 to 45 feet in thickness have been encountered in drilling at Arnaud, Charleswood, 17 miles east of Dominion City, St. Charles (near Winnipeg), and St. Elizabeth. These deposits were passed through at depths of 25 to 260 feet. As these places are scattered between Winnipeg and the international boundary, the results indicate a layer of gypsum throughout that part of Manitoba. As the bed is not far from the surface at some points, further exploration may reveal places where the overburden will permit of inexpensive quarrying.

WESTERN MANITOBA

Gypsum beds have been found in drilling at Gladstone, Leifur, Neepawa, and Rathwell. The depths at which most of the beds were encountered prohibit their exploitation in competition with the surface deposits at Gypsumville, but the 10-foot bed at Leifur is only 10 feet below the surface and has been traced by drilling over several sections.

Production. The total production in 1926 was 35,172 tons.

References: Gypsum in Canada, by L. H. Cole, publication No. 245, Mines Branch, Ottawa.

Non-Metallic Mineral Resources of Manitoba, by R. C. Wallace and L. Greer, Industrial Development Board of Manitoba, Winnipeg.

PETROLEUM AND NATURAL GAS

As these two important materials are so constantly associated in nature, they are described together. They are found in pools or reservoirs in sandstones and other porous rocks, the pores, joints and fissures of which are filled with the oil and gas. The origin of the materials is not known. There are two main theories, (1) the **organic**, which supposes the oil and gas to have been formed by slow alteration of accumulations of animal and vegetable remains, particularly diatoms, (2) the **inorganic**, according to which oil and gas have been formed by the action of subterranean hot water on carbides supposed to exist in the hot depths beneath the rocks. Most geologists favor the first theory.

While small quantities of oil and gas may be found under all sorts of conditions, for the accumulation of the materials in commercial quantities, the following conditions must be fulfilled:

(1) A reservoir, consisting of a porous rock such as sandstone or dolomite.

(2) A capping of impervious rock such as shale or a tight limestone, to prevent the escape of the accumulated oil and gas.

(3) A geological structure to provide for the accumulation of the material, such as an anticline, especially where a cross folding has caused a dome-shape in the fold. There are a number of other geological structures that fulfil this condition, but all lead to the same result, the accumulation of the oil and gas by an upward flow into the pores, joints and crevices of rock that is capped by an impervious layer,

and from which the material cannot escape upward because of the shape of the rock. Where water is absent, gravity may have caused the oil to settle into synclinal and other basins.

Experience shows that where these conditions are not fulfilled, gas and oil in commercial quantities are not found. The discovery of small quantities has often led to expensive drilling in unpromising situations. Such operations should not be undertaken without the advice of a geologist expert in the subject.

Cil and gas have been found in rocks of all ages. Gas has been found even in hard pan above the consolidated rocks, usually in gravel overlain by hard clay. It has also been found in Potsdam sandstone, the oldest of the Paleozoic formations, resting on igneous Precambrian rocks.

Natural gas consists largely of methane or marsh gas, a compound of hydrogen and carbon, with smaller quantities of heavier hydrocarbons (compounds of hydrogen and carbon) that can be condensed into a very volatile gasoline. Natural gas also contains small quantities of carbon dioxide, oxygen, nitrogen, hydrogen, and sometimes helium.

Natural gas is always present in an oil pool. If the top of the pool is drilled into, the well produces gas at first. If the pool is tapped lower down, the pressure of the gas drives the oil to the surface, and an oil well results. Occasionally a reservoir contains gas without any oil.

Petroleum is a mixture of hydrocarbons, some of which are of low boiling point and when separated from the rest constitute gasolene; others of higher

boiling point make kerosene or "coal" oil; other parts are made into lubricating oils, vaseline, grease, paraffin wax and other products. Petroleum contains more or less sulphur, partly as sulphur itself dissolved in the oil and partly as compounds, including the malodorous gas, hydrogen sulphide. Sulphur and its compounds must be removed in the process of refining.

The Cretaceous and Paleozoic rocks may be looked upon as the actual and possible sources of petroleum and natural gas in Manitoba. From the oldest to the youngest, the Paleozoic formations in Manitoba belong to three periods, Ordovician, Silurian, and Devonian.

In the sketch of the Geology of the province, the extent and distribution of these rocks are indicated. (See p. 23).

The possible fields for petroleum and natural gas are the southwest part of the province in the Paleozoic and Cretaceous formations, and the northeast Paleozoic area where Silurian and Ordovician beds underlie the country around the lower reaches of the Nelson and Churchill rivers. The rest of the province is Precambrian and not favorable for oil and gas.

Oil

Oil shale of Cretaceous age outcrops along the eastern flank of the Pasquia, Porcupine, Duck, Riding, and Pembina hills. The shale carries 8 to 10 gallons of oil per ton where it outcrops near Treherne in the valley of the Assiniboine River. This quantity, the largest noted in the province, is not economical-

ly important, but the appearance of oil in the weathered shale has prompted a good deal of drilling. Wells have been put down at Neepawa, Manitou, Treherne, Mafeking, and at Old Man River on the west side of Pasquia hills, but without important results. The presence of oil shale is not necessarily an indication of oil pools. Anticlinal domes, favorable to the accumulation of oil, have not been found in the Cretaceous formations of these hills, and there is no evidence of former oil pools in the outcrops of porous sandstone under the oil shale. These outcrops can be seen at some places along the escarpment formed by the eastern flanks of the hills mentioned, as in the valleys of the Carrot and Swan rivers.

Prospecting for oil has been carried on around **Rapid City,** as far south as Levine, and northward to Minnedosa. This area is underlain by shale. Wells drilled for water, the deepest being 400 feet, have given no indication of oil pools.

On the east flank of the **Porcupine Mountain,** drilling for oil has been carried on in the district around Mafeking. Wells were sunk to depths varying from 1200 to 1800 feet, through Cretaceous shale and sandstone, then through Paleozoic formations. In one hole, granite was reached at a depth of 1562 feet. No indications of oil were found. It is thought that drilling farther west up the escarpment might offer better possibilities.

At **Ochre River,** wells were sunk through shale, limestone, and gypsum, but no oil was found.

Seven miles northwest of **Grandview,** two shallow

holes were drilled through drift and shale, but without important results.

At **Neepawa**, a strong flow of salt water was struck at 1165 feet, gypsum having been passed through at 1100 feet.

South of **Manitou**, a well put down to a depth of 925 feet passed through Cretaceous shales, limestone, and sand, then through Devonian shales and limestone. At 675 feet, in limestone, a strong flow of natural gas was struck. Another flow of gas was tapped at the bottom of the well, with some indication of oil.

Several wells have been drilled in the Paleozoic limestones. The most important one was put down southeast of **Winnipegosis** where the Devonian rocks form a dome. This well reached a depth of more than 1507 feet, but without indications of oil. It should be remembered, however, that one well does not exhaust the possibilities in such a situation.

A hole put down through Paleozoic formations at **Lilyfield**, west of Stony Mountain, reached granite at a depth of 714 feet.

The Silurian and Ordovician area of about 30,000 square miles in the northeastern part of the province is still to be prospected.

Gas

Gas has been found at a number of places near the southwest corner of the province, in an area that includes Waskada, Sourisford, Melita, and Broomhill. In some cases the gas was struck in wells put down in search of water.

At **Waskada** four wells are in use for lighting and heating purposes. The gas from these wells has been

in use for 16 years. It is odorless and dry, and some years ago showed a pressure of 14 pounds.

South of **Sourisford,** gas was struck at a depth of about 200 feet in a well drilled about 20 years ago on the farm of J. B. Elliott. The gas has been used continuously in the farmhouse since that time. There are several places on South Antler Creek in this vicinity where there is an escape of gas.

At **Melita** natural gas was used 20 years ago for lighting purposes in a grist mill.

It is thought that the use of natural gas in the Waskada-Sourisford-Melita district could be much extended by boring wells to supply single houses or small groups.

There is a well on Robert Hall's farm (Tp. 6, Rge. 22 W), in which gas was struck at 190 to 210 feet. The pressure in 1926 was 45 pounds. The gas is 80 percent combustible. This well is about 35 miles northeast of Waskada.

About half way between Winnipeg and Souris, gas has been found near **Treherne** and **Rathwell.** Gas was found on the farm of E. C. Haskell, southwest of Treherne at a depth of 150 feet, and has been used for fifteen years for lighting and cooking. On the farm of Frank Bosc, south of Rathwell, gas was obtained at 170 feet. It has supplied one light for six years. In this area, shale of Cretaceous age overlies limestone. The gas evidently comes from the shale.

Oil Shale

Oil shales are found along the Cretaceous escarpment all the way from Porcupine Mountain in the

north to Pembina Mountain near the international boundary. Samples collected from a number of points yielded crude petroleum ranging from 0 to 7.5 gallons per ton. The oil content of these shales is much too small to be of economic importance. The total thickness of the shale is about 200, and it is possible that systematic search over this large territory may reveal beds high enough in petroleum to be of importance when shale oil can compete with the natural crude petroleum.

References: The Non-Metallic Mineral Resources of Manitoba, by R. C. Wallace and L. Greer, Industrial Development Board of Manitoba, Winnipeg, 1927.

Oil and Gas Prospects of the Northwest Provinces of Canada, by Wyatt Malcolm, Geological Survey of Canada, Memoir No. 29 E, No. 1220.

Cretaceous Shales of Manitoba and Saskatchewan, by S. C. Ells, Mines Branch, Ottawa, Series No. 3, 1921.

HELIUM

Helium is a gas present to a very small extent in the atmosphere and in larger proportions in some natural gas. It is a product of the slow disintegration of radio-active elements such as radium, uranium, and thorium. These elements are present in the crust of the earth in sufficient quantity to account for the amount of helium in the natural gases. The properties of helium make it an ideal gas for filling ballons and dirigible airships. Hydrogen is lighter and so has a greater lifting power, but its combustibility makes it very dangerous. While helium is twice as heavy as

hydrogen, it is not combustible. Its lifting power in air is 88% of that of hydrogen. Of late years it has been used for filling dirigible airships, such as the **Graf Zeppelin** that made the voyage from Germany to the United States and back. As helium is much less soluble than nitrogen in the liquids of the human body it has been suggested that a mixture of helium and oxygen might be used instead of air for supplying deep divers when at their work. As is well known, the diver when ascending must come up in short stages with long rests, so as to allow the dissolved nitrogen to diffuse out of his body. A quick ascent would cause serious swelling or even bursting of the tissues by nitrogen coming out of the blood and other liquids as the pressure lessened. Other proposed uses of helium depend on its superior conductivity for heat.

An investigation of the natural gas fields of Canada has shown the presence of helium in the gas from several fields in quantities that are considered commercial, from 4 to 8 cubic feet of helium in 1000 of gas.

The extremely low liquefying temperature of helium (—269° Centigrade) makes its separation from the other gases theoretically very simple. The gases that are mixed with helium are liquefied at a very low temperature, and the still gaseous helium is pumped off. The natural gas, as it evaporates, goes into the mains for use as a combustible. The machinery by which this separation is effected is much like that for making liquid oxygen.

Reference: Helium in Canada, by H. T. Elworthy, Mines Branch, Ottawa, publication No. 679.

COAL

Nearly all the coal produced in the world comes from rocks younger than the Devonian. While it is true that some coal has been produced from Devonian rocks in Russia, there is so far no indication that this exceptional experience will be repeated in Manitoba.

The Cretaceous formations of southwestern Manitoba have been too little disturbed to produce the pressure that has converted lignite into true coal. The same statement is true of the Eocene rocks of Turtle Mountain. On account of these considerations, the chances of finding commercial bodies of true coal in Manitoba must be considered small.

TURTLE MOUNTAIN

Coal of the lignite variety exists in considerable quantity in southwestern Manitoba in rocks of Tertiary (Eocene) age. The undisturbed condition of the rock beds makes it unlikely that true coal will be found. This coal field is similar to the Estevan field in southwestern Saskatchewan, but the Manitoba field is much smaller and the seams are thin, not exceeding 8 feet and usually much less. The coal seams have been found mostly on the western and northern slopes of Turtle Mountain. The coal has been found usually in drilling wells for water, and has been struck at depths of from 8 to 40 feet below the surface. It is estimated that the Turtle Mountain coal

measures are found within a depth of 200 feet of beds overlying certain beds of sandstone. Two properties have been worked in the past, but no coal is being taken out at present. The **Varden** mine is on section 12, Tp. 1, range 24 W. The seam was struck at a depth of 40 feet, and is 4½ feet thick. A seam 1½ foot thick was struck 12 feet lower down. At another place, three beds of coal, 5½, 3½, and 1½ feet thick, were passed through in sinking a well. The **McArthur** mine is on section 11, Tp. 2 range 23 W. Two seams, 2 and from 1½ to 2½ feet thick, are described as having been worked at depths of 23 to 40 feet.

Recently a 3½ foot seam of coal was found 8 feet below the surface in drilling a well on Powne's farm, section 25, Tp. 1, range 24 W. Analysis of the coal showed that it compares favorably with the Saskatchewan coal mined at Souris.

Dowling estimated the total possible amount of coal in the Turtle Mountain area of 48 square miles as 160,000,000 tons. This assumes an average thickness of 4 feet. While the seams are thin and the lignite will not bear transportation for long distances, this large possible amount of fuel may constitute a reserve for local consumption, when the prices for coal brought from a distance favor the local supply. Even under present conditions it is probable that proper organization would make it profitable to mine the Turtle Mountain coal.

RIDING, DUCK, AND PORCUPINE MOUNTAINS

Lignite occurs in thin seams in Cretaceous sandstone exposed on the east side of these mountains. The beds as seen on the Swan River (S.E. ¼ section 8,

Tp. 37, range 26 W) are only a few inches thick, but are very numerous, some sixty having been counted in one section. It is thought that they represent driftwood deposited at certain seasons and covered by sand. If this is the nature of all the lignite in these rocks, the chance of finding workable seams is not good. On the other hand, much the same explanation was given of the occurrence of scattered lignite in the Cretaceous sand and clay in the Mattagami River in Ontario, but borings recently made have struck beds of lignite up to 35 feet thick. The only information about the Cretaceous lignite of Manitoba has been obtained from the comparatively few exposures in the river and erosion valleys on the east side of Duck and Porcupine Mountains. Drilling higher up on these mountains might reveal thicker coal seams.

References: The Non-Metallic Mineral Resources of Manitoba by R. C. Wallace and L. Greer, Industrial Development Board of Manitoba, Winnipeg.

Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, by D. B. Dowling, Geological Survey of Canada, Memoir 53, No. 1363, Ottawa.

CLAY

Clay is a superficial deposit of very fine-grained material composed more or less of the mineral **Kaolin** or **Kaolinite,** and having the property of making a sticky plastic mass with water. The essential part of clay deposits is a hydrated silicate of aluminum called kaolin when in its pure state. The properties of clay depend largely on the other substances mixed with

the kaolin and also on the physical properties of the kaolin itself. Pure kaolin stands a very high temperature without softening, but if it is mixed with oxides of iron and certain other substances the softening temperature is lowered. The pure mineral burns white, and this is one property that gives its value for making porcelain and other white ware. Oxides of iron give a red or yellow color to the ware.

Kaolin is a secondary mineral, resulting from the alteration of minerals high in aluminum, such as feldspars, micas, and hornblendes. The commonest minerals that change into kaolin are the feldspars, which by the action of water and carbonic acid lose potash, soda, and lime, and at the same time combine with water. It follows that granite, syenite, diorite, diabase, and gabbro, of all of which feldspars are essential constituents, are the usual rocks that form deposits of kaolin by weathering. Of these rocks, granite and syenite are the commonest origins of clay. When the kaolin remains in the position where it is formed, more or less mixed with quartz and other minerals that have not suffered change, it is called a **residual clay deposit.** When it has washed into a hollow, such as a lake basin, it is called a **sedimentary clay deposit.** Deposits that have been mixed with gravel and boulders by glacial action are called **boulder clay.** Boulder clay may have resulted from the transportation of clay beds formed before the glacial period, the ice having mixed clay with stones as it pushed the mass along; or the clay may have been formed from the very fine material produced by the grinding action of the glaciers. Lake Louise is being

slowly filled up with white clay carried into its basin by the streams coming from Victoria glacier.

As Manitoba is a glaciated country, most of its preglacial clay deposits, doubtless very widespread and extensive, have been transported by the ice sheet and converted into boulder clay. Some of the clay was washed out and settled in hollows such as lake bottoms when the ice melted at the close of the last glacial period. These clay beds show stratification, not seen in the boulder clay.

Clay suitable for making bricks and tilts can be found in a great many parts of the province, but certain beds are favored either because of the superior quality of the clay or because of transportation facilities or nearby market. As shale is hardened clay, when its quality is right, it can be ground up with water and made into bricks, tiles, etc. The total value of clay products made in Manitoba in 1927, exclusive of Portland cement, was $201,464.

Crude china clay sells at $6 to $9 a ton f.o.b. at some point at or near the manufactory. Washed and refined china clay is priced at $8.75 to $15 a ton. Clay imported across the Atlantic sells at $14 to $24 a ton, the high price being due to the reputation, careful refining, and uniform quality of the clay. A good deal of china clay is used in the manufacture of paper. Some of the large Canadian paper mills are said to be using 2,000 to 3,000 tons a year.

Kaolin, or China clay, suitable for making chinaware and firebricks has not been found in large quantity in Manitoba. but there is apparently a limited amount of kaolin on Little Deer Island, Lake Win-

nipeg. The Cretaceous clays found in Northern Ontario may possibly extend westward into Manitoba, although there are indications that the basin in which these clays were spread out did not reach so far west.

Clay in Manitoba

Clay suitable for making brick, tile and similar manufactures is plentiful in the province, and there are varieties of shale that are of the right quality for making sewer-pipe and vitrified brick. In the Red River valley the clay is of Lake Agassiz origin, that is, it was laid down on the bottom of the great lake that covered a large part of southern Manitoba during the closing period of the great Ice Age. These clays are of uniform composition, and are bedded and laminated. Other clay deposits have been laid down under recent lakes and rivers. The river-deposited clays often contain lenses of sand, useful to mix with the clay. These lake-, and river-deposited clays are more easily worked because nearer the surface than the Lake Agassiz clays. In 1927, they were the exclusive basis of Manitoba's clay industries.

The surface clays vary a good deal in quality. At Winnipeg, St. Boniface, Whitemouth, and Portage la Prairie, the clay is high in lime. For this reason it burns white or pale buff, the lime forming with the iron oxide and silica a colorless silicate. (See **Silicates** page 2). At Lavenham, Sidney, Firdale, and Edrans, where the clay is comparatively low in lime and high in iron, it burns to shades of red and brown, the color being due to the red oxide of iron (See **Hematite** page 8).

In the banks of the Red River, the Lake Agassiz clay can be seen underlying the 3-foot layer of surface clay to a depth of 20 feet. This forms a very large supply of clay of uniform composition, suitable for the manufacture of brick and tile, but requiring a preliminary heating.

At **Whitemouth** there are beds of sandy clay resting on others apparently of Lake Agassiz origin, both kinds being in regular layers. They make a depth 3½ to 4 feet.

The clay at **Portage la Prairie** is worked to a depth of 7 or 8 feet. It is not bedded and is more sandy in the upper 4 feet than lower down.

At **Sidney** the clay has been worked to a depth of 12 feet. It is interbanded with sand lenses.

At **Edrans,** the clay is worked to a depth of 3 or 4 feet. It contains a considerable quantity of limestone pebbles which are removed by screening. If left in the clay they would be changed to quick lime on burning, and this, by air-slacking, would swell and burst out as unsightly white spots.

At **Gilbert Plains** the clay pit is worked to a depth of 4 feet including the cover of soil. At the east end the clay is high in sand.

Shale

Shales of Cretaceous age underlie the southwestern part of the province and their eastern edge forms the escarpment marked by the Pembina and Tiger hills, Riding Mountain, Duck Mountain and Porcupine Mountain. In addition there are the Eocene shales of Turtle Mountain. The lowest layers of the Cretaceous

shales **(Benton)** are mostly very carbonaceous and would be difficult to burn, as the graphitic carbon burns very slowly and is apt to be left as a black core. The shales of intermediate age **(Niobrara)** are also carbonaceous, but have been used. They grind to a very plastic clay, easily worked and burning to a good red color. Bricks made from this shale are fairly refractory. The youngest Cretaceous shales (**Pierre**) grind to a highly refractory clay, but of low plasticity. A mixture of Niobrara shale from La Rivière and Pierre shale from Morden has been suggested as satisfactory.

These shales are underlain by sandstone (Dakota), and the most refractory shale so far found in Manitoba lies beneath this sandstone. It is seen in the Swan River valley, about 8 miles below Swan River. At one place (Alex. Frasers farm house) there is not more than 3 feet of overburden. This shale, practically a clay, may be suitable for the refractory brick and other materials required in smelting operations.

Bentonite

Bentonite is a peculiar variety of clay that has the power of absorbing a very large proportion of water. At the same time it swells considerably. It has a soapy feel when wet. It is supposed to be an altered volcanic dust. Its principal use is in the manufacture of paper to give it body and weight. It is stated that a small proportion of bentonite mixed with china clay prevents the clay from washing out of the pulp in the process of manufacture. Bentonite has been used as an adulterant in cheap candy and for a number of other purposes.

Clay having the properties of bentonite occurs in a Cretaceous formation (Upper Niobrara) in the Pembina valley where it is exposed to a depth of 50 feet in a number of places from the international boundary to the E½ of Section 23, Tp. 2, Rge 9W; also in Dead Horse valley and on the east side of Pembina escarpment.

References: A. McLean, Geological Survey of Canada, Summary Report, 1914, Pembina Mountain, Manitoba.

The Non-Metallic Mineral Resources of Manitoba, by R. C. Wallace and L. Greer, Industrial Development Board of Manitoba, 1927, p. 77.

Clay and Shale Deposits of the Western Provinces, by Joseph Keele, Memoir No. 66, Part V, 1912, Geological Survey of Canada.

Bentonite, by Hugh S. Spence, Mines Branch, Ottawa, publication No. 626.

CHAPTER XIV

NON-METALLIC MINERALS (Cont'd)

LIMESTONE, DOLOMITE, CEMENT, ETC.

LIMESTONE

Limestone is essentially carbonate of lime, (calcium carbonate) but this is always mixed with more or less of other substances. When the rock contains more than a small percentage of carbonate of magnesia, (magnesium carbonate) it is called **magnesian** or **dolomitic limestone,** and when the proportion of the two carbonates is about even, (theoretically 54.35% carbonate of lime and 45.65% carbonate of magnesia), the rock is **dolomite.** It is harder than calcite limestone, and quarrymen often call it **hard limestone.** Carbonate of lime as a distinct mineral is called **calcite.** Its color is white, so that the various shades of color seen in limestones are due to the impurities.

Limestone is a sedimentary rock formed of the shells of minute and sometimes larger shellfish. The animals make their shells by extracting calcium carbonate from the water. Part of this material is precipitated directly from the water. The sediment thus formed in past ages has become the solid rock known as limestone. From its

method of formation, it can be seen that some beds would have clay and even very fine sand mixed with the calcium carbonate. Thus have been formed **argillaceous (clayey) limestones** and **siliceous limestones.**

It is seen that limestones vary a good deal in color, hardness, and composition. It is necessary to select a limestone of the right composition for any one of the many uses to which it is put. This selection can be made only by chemical analysis. But a certain bed or layer is apt to be fairly uniform in composition.

The ordinary sedimentary limestone often shows little or no grain, but it is sometimes semi-crystalline. Older limestones have underone a change due to heat from masses of igneous rocks, and in part to heat generated by pressure. These agencies have caused crystallization. The crystals may be small or larger. At the same time the impurities that gave the gray, yellow, buff, or bluish color to the original stone have more or less completely disappeared, and the limestone may have become white. This altered rock is called **crystalline limestone.** When the grain, color, and other properties are right, the stone is useful as **marble.** Crystalline limestone often contains inclusions of granite and gneiss, grains and stringers of quartz, tourmaline, pyrite, magnetite, feldspar, pyroxene, flakes of mica and graphite, and other impurities that make it useless for many industrial purposes.

Calcite is sometimes deposited in veins of such size and purity as to be of commercial importance.

USES

Building Stone. The unaltered beds of limestone make good building stone, easily quarried and worked, and often of pleasing appearance.

To be suitable for building stone, limestone must be free from materials such as pyrite and siderite that cause a rusty stain on weathering. It must also be free from shaley partings that impair the strength of the stone. The thickness of sound layers should be great enough to give suitable blocks of stone. The thinner layers are sometimes used for foundations, and for crushed stone for concrete and railway ballast.

The use of limestone as building stone has been much affected by the growing use of concrete for many construction purposes, but it is probable that there will always be a demand for limestone of a pleasing color and good general appearance.

Lithographic Stone. For making lithographs a limestone is required of very fine grain, and free from cracks and grains of hard minerals. There must also be no crystallized carbonate of lime to mar the uniformity of the texture. So far, no stone has been found in Canada from which large enough slabs can be cut of the required quality.

Portland Cement. For making Portland cement, the materials required are clay and limestone. In Canadian cement works marl is used largely instead of limestone. Marl is a carbonate of lime deposit found in the bottoms of shallow lakes or in places where such lakes have been drained by some natural change

in levels. Limestone not suitable for some purposes because of the large proportion of shale in it may be satisfactory for making cement, as the shale is often of the same composition as clay.

Sulphite Pulp Process. Most of the pulp and paper made from wood is manufactured by the sulphite process. This involves heating the prepared wood in sulphite liquor, made by treating limestone and water with sulphur dioxide gas made by burning sulphur or iron pyrites. The resulting liquor is a solution of bisulphite of lime. The limestones preferred for this purpose are those as high as possible in magnesia so that the liquor contains also bisulphite of magnesia. The limestone must be free from impurities that would be carried into the paper and spot it. This rules out some crystalline limestones that contain flakes of graphite and black mica. The high magnesia limestone is preferred because of the sparing solubility of sulphate of lime, formed in some quantity during the process. It may crystallize in the paper as gypsum and spoil the texture of the paper. Sulphate of magnesia, being very soluble, easily washes out.

Limestone as a Flux. In smelting operations limestone is often used as a flux, that is, to combine with silica and other materials in the ore so as to make a slag that will flow easily. Large quantities are used for this purpose in the manufacture of pig iron. If copper and nickel ores are siliceous, lime is used in smelting them. In the manufacture of pig iron, limestone high in magnesia is preferred, as the magnesia tends to carry off the sulphur. For the manufacture

of pig iron, the limestone must be very low in phosphorus and sulphur.

Glass Manufacture. Common glass is a mixture of silicates including silicate of lime and silicate of soda. The lime silicate requires limestone. Carbonate of soda and glass sand supply the other materials. For glass-making a limestone low in magnesia is best as magnesia tends to raise the melting point of the glass.

Lime. Lime is calcium oxide, made by strongly heating limestone so as to drive off carbon dioxide. This gas is sometimes collected, liquefied by compressing it in steel cylinders, and used for various purposes including the making of fizzing drinks. If the limestone contains carbonate of magnesia, the resulting lime is a mixture of calcium oxide and magnesium oxide (magnesia). A "fat" lime is one having little magnesia in it. In slaking or hydrating lime, the calcium oxide combines with water, and this operation generates a good deal of heat. Magnesia combines very slowly with water and there is little generation of heat. Thus, in the process of slaking, a fat lime gives off more heat than a high-magnesia lime.

Lime has a large number of uses, including the making of mortar for laying bricks and stones, the manufacture of sand bricks, silica bricks, calcium carbide, acetate of lime, chloride of lime, calcium chloride, etc. It is used in the purification of beet sugar and for removing the sulphur from coal gas. An important use is for furnace linings for the basic steel process. The lime removes phosphorus from the steel and thereby improves its quality.

For these various uses the lime must be made from suitable limestones. High calcium limestones are preferred for most purposes, but other requirements must be fulfilled. For example, lime for making calcium carbide must be free from phosphorus.

Whiting, Stucco Dash, etc. Crystalline limestone of good quality has been ground and used as a substitute **for whiting** made of chalk, and for other purposes.

Well-crystallized calcite that breaks with good cleavage is used as **stucco-dash, etc.**

Iceland Spar is very perfect crystals of calcite used in making certain parts of optical instruments. For this purpose the requirements are very exacting, including perfect transparency, freedom from cracks and other flaws, and absence of any distinct color other than a pale yellow. Crystals satisfying the requirements have been found in very few places. The Iceland locality cannot supply the world's requirements, and other sources are eargerly sought by the optical instrument makers. Iceland spar of the best quality sells for $10 to $20 a pound.

Limestone in Manitoba

Manitoba limestones range in composition from high-calcium stone containing 90 per cent or more of calcium carbonate to dolomite containing more than the theoretical percentage (45.65) of magnesium carbonate for dolomite. The limestones also vary in another respect which influences their suitability for certain purposes, viz. the percentage of substances insoluble in acids. This "insoluble" consists largely of silica, and when it is too high, the limestone is not

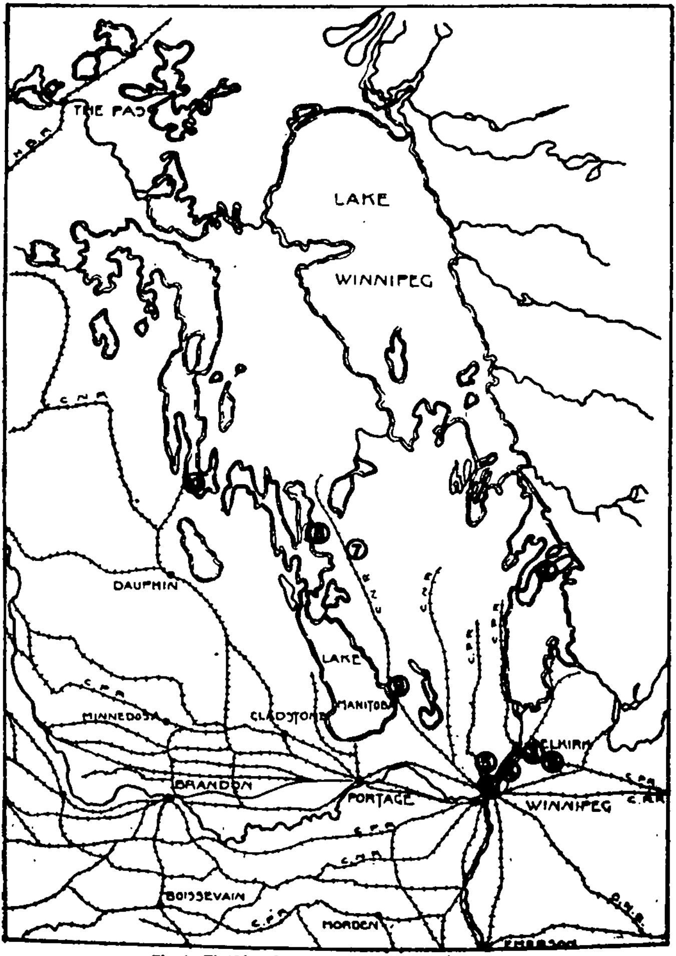


Fig. 6—The More Important Limestone Occurrences—

1. Hecla island
2. Garson
3. East Selkirk
4. Lower Fort Garry—St. Andrews Locks
5. Stony mountain
6. Little Stony mountain
7. Spearhill
8. Steep Rock
9. Oak Point
10. Winnipegosis

suitable for some purposes such as the manufacture of bisulphite liquor for making pulp. A good deal of the limestone available in Manitoba is free from this objection.

With regard to distribution, the southern part of the province is well supplied as far north as the Flin Flon region, south of which, the Paleozoic formations cease. Far north, around Nelson and Hayes rivers, Paleozoic limestones are found. The crystalline limestones of the Grenville series, so plentiful in parts of Ontario and Quebec, have not been discovered in the Precambrian regions of Manitoba. Crystalline limestone occurs in Saskatchewan west of the Cold Lake area, and it is possible that it may yet be discovered on the Manitoba side of the boundary. The Cretaceous limestone and chalk of southwest Manitoba is mostly high-calcium stone, soft, and sometimes high in "insolubles." At Babcock, calcareous shale, or limestone high in clay material, was quarried from 1907 to 1924 to make natural cement. (See **Cement** p. 248). Both the Paleozoic and the Cretaceous limestones are flat-lying and are therefore mostly covered with a deep overburden. They are often exposed in the banks of rivers and on lake shores. Other outcrops suitable for quarrying are found where erosion and glaciation have left thin overburden, rocky elevations, and escarpments, as at Garson and Stony Mountain. Over a large part of Manitoba limestone is abundantly available for present and future requirements.

Ordovician Limestones

Limestones of Ordovician age have been most used in Manitoba. Ordovician formations, mostly lime-

stone, form a band extending from the international boundary northward to Lake Winnipeg of which the western shore and most of the islands are of Ordovician limestone. This band reaches as far north as Wekusko (Herb) Lake. It skirts the south side of the northern mineral region to the Saskatchewan boundary. In its southern part it is traversed by many railway lines, and Lake Winnipeg affords water transportation from favorable quarry points to manufacturing centres. Ordovician limestones form another large area along the Hayes, Nelson, and Churchill rivers in the Hudson Bay region. The Ordovician limestones are mostly high in magnesium, and some varieties are dolomite, as for example the stone of the Stony Mountain quarries. The dolomitic character gives the strength and hardness desirable in building stone.

Stony Mountain. The City of Winnipeg quarry is at this place, about 12 miles north of the city. The limestone beds are 14 feet thick. The stone is high in magnesia and in insoluble. Crushed stone for Winnipeg streets is produced. Part of the stone is used for rubble, tennis courts, and stucco.

Little Stony Mountain. Quarries have been operated along a low ridge from six to nine miles north of Winnipeg. The beds are not so thick as at Stony Mountain. Very great quantities of stone are availble, but the overburden is thick, from two to five feet.

Lower Fort Garry. The beds of limestone, formerly quarried at the Stone Fort, are 8 to 10 feet thick. The stone was used for making lime and for building

stone. The same beds were formerly worked at St. Andrews Locks.

Garson. The Garson quarries are at the east end of a ridge that extends westward to East Selkirk where quarries were operated many years ago. The Garson stone is considered one of the best building stones in Canada. It is a comparatively soft limestone of a characteristic mottled appearance, the color being buff in one variety and blue in another. The stone can be taken out in large blocks and its cutting and dressing properties are good. The amount of stone available is very large. The beds make up a thickness of 30 feet, and they are known to extend north and south for about 3 miles, and east and west from section 33, Tp. 12, Rge. 6 E, to section 15 Tp. 13, Rge. 6E. The heavy covering on a large part of this area reduces the easily worked part to a ridge about half a mile wide. This limestone is fairly high in magnesia, but low in "insoluble." Three quarries have been in operation of late years, under the **Tyndall Quarry Co.**, the **Western Stone Co.**, and **Gillis Quarries Ltd.** Electrical power is used. Most of the product is used as building stone, but small quantities are used for riprap and rubble, and waste stone is used to a small extent in making lime. The Legislative Buildings in Winnipeg are built of this stone, and it has been used for interior finish in the Parliament Buildings, Ottawa. The St. Roch Cathedral, Quebec, is built of Garson (Tyndall) limestone.

Hecla Island. This island is near the north end of the southern expansion of Lake Winnipeg. On the east shore of the island is a cliff of limestone half a

mile long. The stone is fairly high in magnesia and "insoluble." The beds are too thin to make building stone. The quarry has been worked by the Lake Winnipeg Shipping Company, the product being shipped to Winnipeg by barge for use as rubble and crushed stone.

Other Outcrops. Ordovician limestone outcrops at a number of other points on the shores and islands of Lake Winnipeg, including Grindstone Point, Bull Head, Dog Head, Black Bear Island, Tamarack Island, Jack Head Island, Robinson Point, Howell Point, Firmont Island, McBeth Point, and Cat Head. It also outcrops north of Arborg and near the mouth of Fisher River. Some of the limestone near Arborg is very pure, containing less than 3 per cent of impurities.

Silurian Limestones

Silurian limestones and other formations underlie much of the country between Lake Winnipeg on the East and lakes Manitoba and Winnipegosis on the west. The Silurian band extends southward past Winnipeg to the international boundary, and northward beyond the Saskatchewan River. Another Silurian area of over 4,000 square miles lies around Port Nelson, Hudson Bay, and the limestone outcrops along the Nelson River.

The Silurian limestones of Manitoba are mostly dolomite. In Southern Manitoba, the stone is usually fine-grained, tough, and hard.

Stonewall. The quarries of the Winnipeg Supply and Fuel Co. are near the Winnipeg Beach highway and not

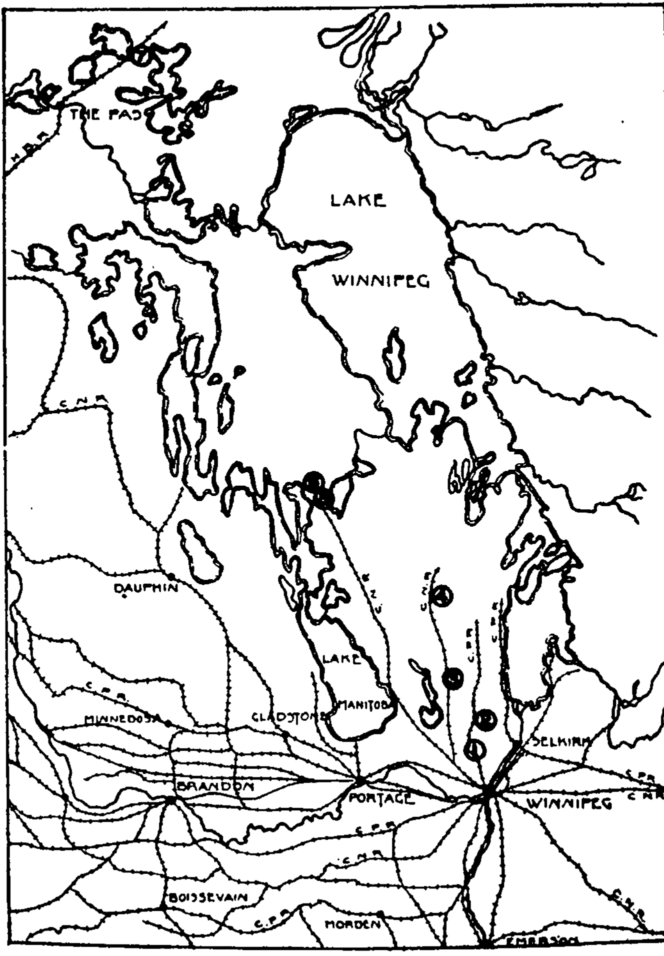


Fig. 5—The More Important Dolomite Occurrences—

1. Stonewall
2. Gunton
3. Inwood
4. Broad Valley
5. Fairford
6. Old Gypsumville
7. Mile 42—Hudson's Bay Railway

far from a Canadian Pacific railway branch running north from Winnipeg. The stone is taken from two quarries close to the town of Stonewall on the north and east sides. The overburden is 5 to 7 feet deep, followed by 2½ feet of broken stone. Under this is 10 feet of beds of white, fine-grained, mottled stone that makes a very white lime, slow-,and hard-setting. In addition to burning for lime, some stone has been used locally for building purposes. Below the 10-foot quarry beds is 3 feet of hard beds used for crushed stone. The Stonewall dolomite is low in "insoluble" and other impurities.

Gunton. For a number of years quarries were worked near the village of Gunton and close to the same Canadian Pacific railway line near which the Stonewall quarries lie. The stone was used for crushed stone and rubble. A large quantity is readily available and the overburden is not deep. These quarries have not been worked recently.

Inwood. Some years ago a small quarry was operated 1½ miles northwest of the village of Inwood on the Hodgson branch of the Canadian National railway running north from Winnipeg. The stone was used for making lime. A 16-inch top bed may be suitable for building stone. Below this is a white, very fine-grained dolomite. The over burden is very light or absent over a considerable area.

Broad Valley. A number of years ago a small quarry was worked one mile north of the village, which is on the Hodgson branch of the Canadian National railway. A low escarpment and light overburden make quarrying operations easy. The lower beds are white,

exceedingly fine-grained, similar to the lower beds at Inwood.

Fairford and Old Gypsumville. Small amounts of dolomite have been taken out near these two places, which are on a branch of the Canadian National railway running from Winnipeg east of Lake Manitoba. The stone is suitable for rubble; no high-grade building stone has been found. A very large quantity is available at Old Gypsumville.

Hudson Bay Railway. Some stone supposed to be of Silurian age was taken out near Cormorant Lake, mile 42 from The Pas. It was used for railway construction purposes. The rock is not suitable for building stone.

Devonian Limestones

Devonian formations, mostly limestones, underlie the region in which are the basins of Lake Manitoba and Lake Winnipegosis. There are three limestone formations, the **Manitoban limestone**, the **Winnipegosan dolomite**, and the **Elm Point limestone**. The Manitoban limestone outcrops on Lake Winnipegosis on Snake Island, southwest of Charlie Island, Mouth of Mossy River, west side of Pelican Bay, west side of Swan Lake, on Red Deer River, and on the south shore of Red Deer Lake. The Winnipegosan dolomite is exposed on Lake Winnipegosis at Whiteaves Point, Salt Point, Hill Island, Pemmican Island and on the islands in Toutes Aides Bay, Lake Manitoba. The Elm Point limestone outcrops two miles north of Oak Point and on the shore of Lake Manitoba, immediately north of Elm Point and four miles northeast of Moosehorn,

and at Point Brabant and Graves Point on Lake Winnipegosis.

Spearhill. The village of Spearhill is about 5 miles northeast of Moosehorn with which it is connected by a spur line from the Winnipeg-Gypsumville branch of the Canadian National railway. The quarry of the **Moosehorn Lime Co.** is close to the village .The stone is easily taken out from a quarry face of 11 feet height in a hillside. Partings and joints reduce the stone to an average thickness of about 3 inches. It is a high-calcium limestone (96.5 per cent $CaCO_3$) making a lime of good quality and suitable for making sulphite liquor for pulp manufacture. The production for both these purposes is large.

Steep Rock. The quarries are on Portage Bay, Lake Manitoba, and are connected by a spur line with the Winnipeg-Gypsumville branch of the Canadian National railway. Large scale operations are carried on by the **Canada Cement Company** to supply limestone for the cement works at Tuxedo near Winnipeg, 146 miles to the south. The high-calcium content of the stone makes it suitable for cement manufacture. (See **Cement** p. 248). The production is from 3000 to 4000 tons a week from May to December.

Oak Point. The quarry of the **Winnipeg Supply and Fuel Co.** is on the shore of Lake Manitoba 2½ miles north of Oak Point station on the Winnipeg-Gypsumville branch of the Canadian National railway. The stone is higher in magnesium carbonate (6.81 to 7.19 per cent) than the Spearhill stone. The overburden is light over a considerable area, but the floor of the

quarry is on a level with the lake, necessitating pumping. The stone was used for making lime, but the quarry has not been operated since 1923.

Winnipegosis. A small quarry is operated by the **Canada Gypsum and Alabastine Company** about 1¼ miles west of Winnipegosis. The village is the terminus of a branch line from Sifton Junction on the Canadian National railway. The stone is very white and fine grained. It is low in magnesium carbonate and in "insoluble." It is used in the manufacture of whiting. Eight miles southeast of Winnipegosis is a similar limestone. It has been quarried to a small extent.

Cretaceous Limestones

Soft chalky limestones occur in the Cretaceous formations of Southwestern Manitoba, and outcrops are seen on the banks of the Assiniboine and Pembina rivers, and on Riding, Duck, and Porcupine mountains. In respect of low magnesia content, these limestones are suitable for cement manufacture, and some of the Assiniboine River beds are suitable in other respects for making Portland cement, although the thinness of the beds and difficulties of deep overburden or of transportation may lie in the way of their utilization. Some of the deposits are described as calcareous shale or clayey limestone, mixtures of clay (more or less hardened) with calcium carbonate. A bed of this material was worked at **Babcock** from 1907 to 1924 by the **Commercial Cement Co.** (See **Cement** p. 248.)

CEMENT

By far the greater part of the cement used in construction of buildings. foundations, dams, etc., is **Port-**

land cement, but natural cements made from calcareous shale and similar materials have been a good deal used in the past. Their use seems to be declining.

Commercial Cement

Commercial cement is the name given to a natural cement made at Babcock from a calcareous shale containing about 70 per cent of calcium carbonate, the remainder being mostly clayey material. The rock is higher in oxides of aluminum and iron than the mixtures used for making Portland cement, but the content of silica is about the same. At Babcock, the rock has been taken out by tunnels driven into the bank, a more expensive operation than quarrying. The cement is made by heating the rock in continuous kilns and grinding the resulting clinker, after carefully removing underburned and overburned pieces. Large quantities of this natural cement have been used as a mortar and to mix with Portland cement for street and sidewalk construction. The Babcock works of the Commercial Cement Co. were active from 1907 to 1924, but have not been making cement since 1924.

Portland Cement

Portland cement is made by burning a carefully selected and controlled mixture of clay and limestone so as to give a product containing approximately 60 to 65 per cent of lime, 20 to 25 per cent of silica, and from 5 to 12 per cent of aluminum and iron oxides. Marl has been much used instead of limestone in Canadian cement works. It is a deposit of calcium carbonate found on the bottoms of some shallow lakes or where such lakes have dried up. Shale is sometimes

used instead of clay. The limestone and clay are well mixed by grinding, the mixture is heated to a very high temperature, and the resulting clinker is ground to a fine powder. To retard the initial setting of the cement gypsum (3.6%) is added to the clinker.

Canada Cement Co. The only Portland cement plant in operation in Manitoba is that of this company at Tuxedo, south of Winnipeg. The limestone is brought from the Company's quarry at Steep Rock (See **Limestone**, p. 246). Clay is excavated by steam shovel at the works. The plant uses 150 to 200 tons of Alberta coal per day, and more than 4500 tons of gypsum is used annually. The present capacity of the plant is over 5000 barrels of cement a day. The plant operates only about seven months in the year, and this allows an annual production of more than 1,000,000 barrels of cement. The product of the Tuxedo plant supplies the district from Dryden to Moosejaw.

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